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Implementation of video teleconferencing for the Republic of China Navy

Chen, Chung-Wei

Monterey, California. Naval Postgraduate School

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FOR THE REPUBLIC OF CHINA NAVY

by

Chen, Chung-Wei

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Teleconferencing has been proposed for the Republic of China Navy (ROCN) to reduce costs and increase productivity, while improving communications. The ROCN's need for a modern teleconferencing system is due to the continuing threat from communist China and an ever-increasing number of meetings required for exchange of information and optimal decision making. The basic information concerning teleconferencing technology is discussed. Five categories of teleconferencing systems used throughout the world are described and five kinds of transmission media compared. Human factors system design considerations related to a videoconferencing system in Taiwan are provided. The system design considerations include vision, acoustics, space, temperature, humidity, equipment, and security. A seven-step economic analysis methodology is proposed to evaluate the costs-versus-benefits feasibility of any selected teleconferencing system. This methodology is used to provide evidence that a fiber optics-linked videoconferencing system for the ROCN will be cost effective if it is used for at least 35 meetings each year.

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Implementation of Video Teleconferencing for the Republic of China Navy

by

Chen, Chung-Wei
Lieutenant, Republic of China Navy
B.S., Chinese Naval Academy, 1981

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Author: Chen Chung Wei
Chen, Chung-Wei

Approved by: Judith H. Lind
Judith H. Lind, Thesis Advisor

William J. Haga
William J. Haga, Second Reader

David R. Whipple, Chairman,
Department of Administrative Science

ABSTRACT

Teleconferencing has been proposed for the Republic of China Navy (ROCN) to reduce costs and increase productivity, while improving communications. The ROCN's need for a modern teleconferencing system is due to the continuing threat from Communist China and an ever-increasing number of meetings required for exchange of information and optimal decision making. The basic information concerning teleconferencing technology is discussed. Five categories of teleconferencing systems used throughout the world are described and five kinds of transmission media compared. Human factors system design considerations related to a videoconferencing system in Taiwan are provided. The system design considerations include vision, acoustics, space, temperature, humidity, equipment, and security. A seven-step economic analysis methodology is proposed to evaluate the costs-versus-benefits feasibility of any selected teleconferencing system. This methodology is used to provide evidence that a fiber optics-linked videoconferencing system for the ROCN will be cost effective if it is used for at least 35 meetings each year.

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LIST OF ACRONYMS AND ABBREVIATIONS

AT&T	American Telegraph and Telephone
bps	Bits per second
CCITT	Consultative Committee of International Telegraph and Telephone
CLI	Compression Labs, Incorporated
Codec	Coder-decoder
DBM	Decibel in mili-watts
DC	Direct current
DGT	Directorate General of Telecommunications
DoD	Department of Defense
EIA	Electronics Industries Association
Gbps	Giga bits per second
GHz	GigaHertz, 10^9 Hz
ISDN	Integrated Services Digital Network
Kbps	Kilo bits per second
kHz	KiloHertz, 10^3 Hz
LAN	Local area networks
LED	Light emitting diode
LOS	Line of sight
Mbps	Mega bits per second
MHz	MegaHertz, 10^6 Hz
NASA	National Aeronautics and Space Administration
NEC	Nippon Electric Corporation
NTSC	National Television System Committee
PAL	Phase-alternating line
RF	Radio Frequency
ROC	Republic of China
ROCN	Republic of China Navy

SNR	Signal-to-noise ratio
THz	TeraHertz, 10^{12} Hz

I. INTRODUCTION

Rapid advancements in communications and transmission technologies, coupled with today's need to deal with more complex and numerous decision making situations, are expected to result in the widespread adoption and utilization of teleconferencing systems in the coming years. It is therefore important that military organizations understand the functions of these systems. The limits of teleconferencing systems also must be recognized, especially as these limits relate to transmission media, human factors, and the impact of teleconferencing systems on decision making processes. Military organizations also must evaluate the cost of such systems so that they may be implemented for the most effective and efficient use. The purpose of this study is to explore the above teleconferencing system factors as they are expected to affect the Republic of China Navy.

A. BACKGROUND

1. Communications Environment, Needs, and Plans

Taiwan is a leaf-shaped island straddling the Tropic of Cancer about 200 kilometers (120 miles) off the eastern shore of the Chinese mainland (see Figure 1 on page 2). Strategically located in the East China Sea, midway between Japan and Korea to the north, and Hong Kong and the Philippines to the south, Taiwan stretches about 386 kilometers (240 miles) from north to south and 137 kilometers (85 miles) across its widest points from east to west. [Ref. 1:p. 7] With a land area of 36,000 square kilometers (13,900 square miles),

Taiwan is approximately the size of the Netherlands, and is one-twelfth as big as the state of California.

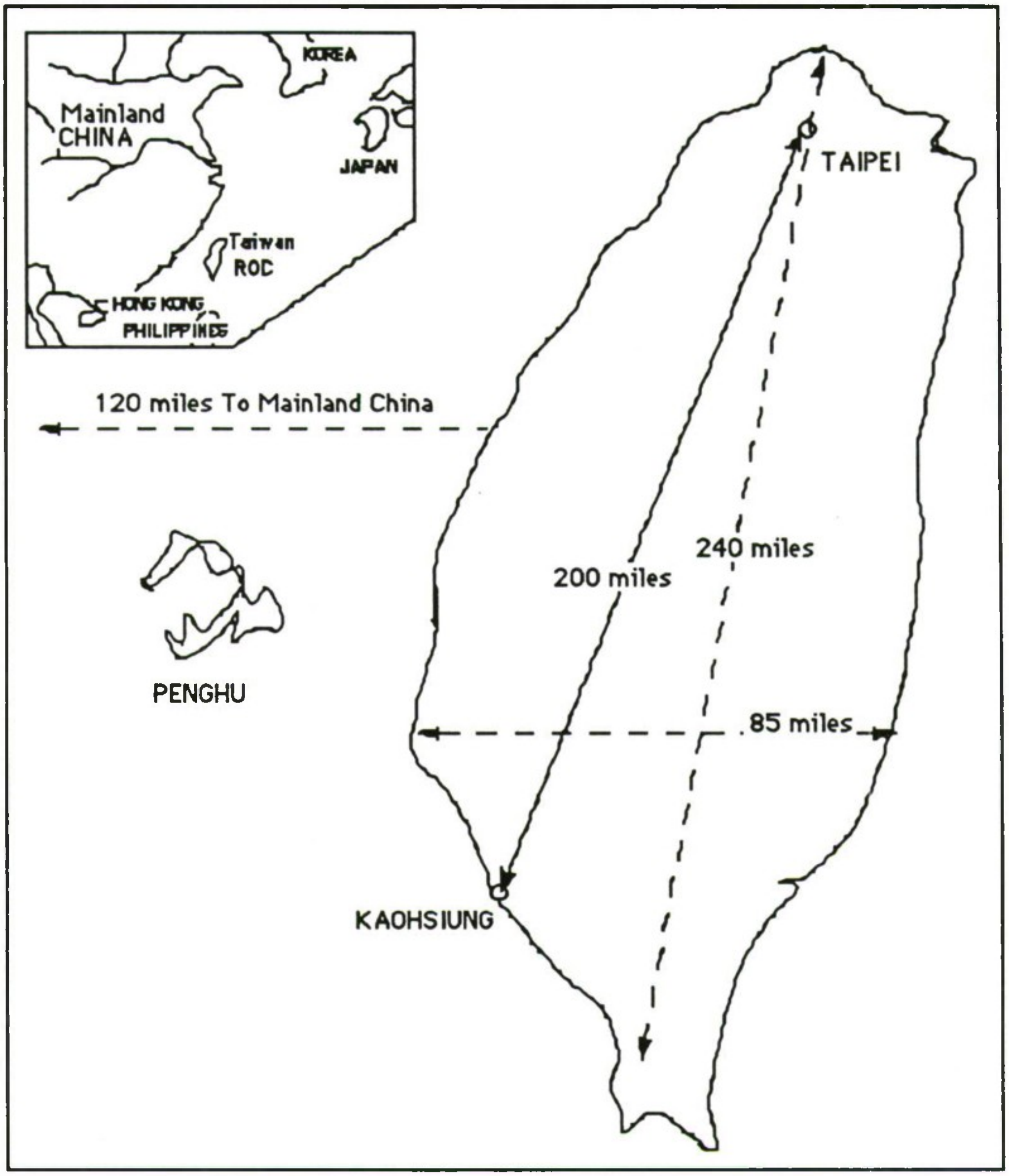

Figure 1. The Republic of China on Taiwan
[Ref. 1:p. 7]

With a population of 20 million people, the Republic of China (ROC) on Taiwan is the second most densely populated country on earth as of May

12, 1989 [Ref. 1:p. 7]. About 2.8 million of those people live in Taipei City and 1.4 million in Kaoh-shiung, metropolitan areas in the north and south of Taiwan respectively. California, which is 158,693 square miles in size, is 11.42 times bigger than Taiwan. Yet California's 28.17 million population is only about 1.4 times as large as the population of Taiwan [Ref. 2:p. 21].

A country with a telephone density of over 30 phones per 100 people is considered to be a developed country. Under 30, it is considered a developing country, and under five it is labeled as underdeveloped. The ROC population density is 1439 people per square mile. The country had approximately 7.4 million telephones in December 1988, with the number increasing at the rate of 600,000 annually [Ref. 3:p. 38]. Thus telephone density of the ROC is 37.1 per 100 people. This may be compared with California's population density of 178 per square mile [Ref. 2:p. 21], and telephone density of 49.69 per 100 people [Ref. 4]. Although already qualified as a developed country, the ROC should expect continued growth in telecommunications services. In addition, the need for telecommunications services in Taiwan has dramatically increased due to a strong economy and serious automobile traffic problems resulting from the population density of the island.

The ROC government initiated a "Telecommunication Modernization Plan" in 1984, one of the government's 14 major construction plans for upgrading of the living environment and the enhancement of national economic development. The plan includes 26 subplans covering every aspect of the proposed service networks of the Directorate General of Telecommunications (DGT). The plan estimates the cost of the project at approximately NT$65.3 billion ($2.612 billion, U.S.). According to the

Planning Department of the DGT, "...it is the most important construction project ever planned by DGT" [Ref. 5:p. 270].

During the six-year period of this plan (1985-1990), the service networks will evolve from analog to digital systems and serve as the foundation for the Integrated Services Digital Network (ISDN) in the future. Additionally, this plan will introduce various advanced systems to the network for providing new services [Ref. 6:p. 93]. These services will include Universal Database Access, Public Information Processing, Electronic Mail, Videotex, Teleconferencing, etc.

2. Republic of China History and Threat of Invasion

Since 1949, China has been divided into two regimes. The Republic of China is located on the east side of the Taiwan Strait. The People's Republic of China, located on the Asian Mainland, has been governed by the Communist Party for the last 40 years. During 40 years of struggle and competition between Communist China and the ROC, the ROC has prospered economically, and continues to seek to reunify China under a democratic regime based on Sun Yat-Sen's ideals, that is, the *Three Principles of the People* [Ref. 7:p. 14]. During this time, Communist China has not prospered to the same extent. There is a continued threat that it might use force to overtake Taiwan, based on political, military, and economic motives.

Communist China's leader Teng Hsiao-Ping, in talks with Philippine Vice President and Foreign Affairs Minister Salvador Laurel, declared explicitly on June 17, 1986, that "...when patience runs out and peaceful compromise is refused, there is no other way but force" [Ref. 7:p. 2]. In September, 1989, Teng stated: "...never exclude the possibility of using force to

reunify China" [Ref. 8:p. 1]. Although the situation of the Taiwan Straits appears calm on the surface, there is a dangerous current underneath. It is very important that the ROC take the threat of Communist China into account while planning and developing all national assets. This is especially true for telecommunications systems.

B. PROBLEMS RELATED TO ROCN COMMUNICATIONS

The Republic of China Navy (ROCN) has plans to develop a modern defense telecommunications network for military purposes. As Fijol and Woodbury noted, "In the years to come, decision makers will face even stronger pressure to participate in an ever increasing number of meetings to facilitate greater and faster exchange of information" [Ref. 9:p. 10]. Such meetings can be difficult to arrange, and often are expensive both in terms of money and time. Decision makers may find it increasingly difficult to get together physically for required meetings.

As a result, the ROCN is considering taking advantage of the DGT's modernization plans to set up a domestic teleconferencing system to facilitate the military decision making process. This system could provide the lead for the other military services and would have the capability for expansion as a major part of the Department of Defense (DoD) ISDN system. Since the Navy's proposal in 1986, many kinds of teleconferencing systems have been studied. Not all varieties would be appropriate for the ROCN. Thus, the ROCN needs to understand the characteristics of the different kinds of teleconferencing systems, including how each system would be affected by the ROCN's unique situation and needs, in order to plan and develop an optimal system.

C. GOALS AND OBJECTIVES

The goals of this study are to locate, analyze, and document information that can assist the ROCN during development of a military teleconferencing system. This information includes the following items.

- What a teleconference system can do for the ROCN.
- The kind of teleconference system that would best meet the ROCN's needs.
- The things that must be considered in order to develop an optimum teleconferencing system.

In order to achieve these goals, several objectives must be met. These objectives include the following.

- Documentation of how different kinds of teleconferencing systems function and how transmission media are used, in order to make an optimal selection for a given environment.
- Documentation of how human factors affect the functioning of a teleconferencing system, in order to assure that system design will facilitate user acceptance and implementation.
- Determination of available cost and benefit evaluation methodologies, in order to identify evaluation plans for ROCN analysis proposed teleconferencing systems.

D. ORGANIZATION AND SCOPE

Although the thrust of this study is to provide information needed by the ROCN, this thesis presents information on a wide range of topics related to teleconferencing systems. Information sources include government agency reports, academic publications, teleconferencing system manuals, handbooks, brochures, market statistics analyses, interviews, textbooks, and articles from periodicals.

The material is organized into separate chapters, each emphasizing a different aspect of teleconferencing information. The second chapter

describes teleconference technology and information needed for the selection of transmission media. Chapter three focuses on the impact of human factors in teleconferencing. Chapter four offers an approach for cost and benefit analysis, based on available methodologies. The fifth chapter provides conclusions reached during this study, and recommends directions for further research.

II. TELECONFERENCE TECHNOLOGY

Teleconferences--electronic meetings--are in the forefront of today's new communications technologies. They are part of what are referred to as the information age, the electronic age, the office of the future, the television age, the communications revolution, and the computer age. However one chooses to categorize teleconferences, they are already standard features in many of the largest corporations and institutions, and are fast becoming communication tools to be reckoned with by all kinds of organizations: businesses, universities, unions, medical centers, government agencies, professional associations, social service departments, etc. [Ref. 10:p. 45]

The market for teleconferencing is booming. It is necessary to know how to design and develop a teleconferencing system, before deciding which is the best tool. This chapter provides some detailed but nontechnical explanations of the major aspects of teleconferencing systems.

A. BACKGROUND OF TELECONFERENCING

1. Definition

Based on definitions by various authors, this study will define teleconferencing as: "a structured, interactive, scheduled, electronic meeting between two or more remote locations among a group of people, for the purpose of sharing remote resources." [Refs. 11:p. 2; Ref. 12:p. 74; Ref. 13:p. 80; and Ref. 14:p. 9]

2. History of Video Teleconferencing

Snead and Duncan note that teleconferencing is not a new concept [Ref. 15:p. 7-40]. On 7 April 1926, then Secretary of Commerce Herbert Hoover spoke on a videoconference system with Walter S. Gifford, president of American Telegraph and Telephone (AT&T). Over the next 30 years, Bell Laboratories continued to work on that system to improve on it and to develop it for commercial use. By 1956, Bell Labs was ready to demonstrate their videoconference system to the Institute of Radio Engineers. That system was crude by today's standards, with separate components used to make up each part of the videoconference unit. Soon, Bell engineers were able to incorporate the separate components into a single complete unit, and, in 1964, this system was shown to the public. Taking action on recommendations from the public, Picturephone was developed a year later and promised to become a best-selling product of the future. [Ref. 16:p. 7]

In 1969, Picturephone was operationally tested with the assistance of the Westinghouse Electric Company. A line between Westinghouse offices in Pittsburgh and New York was installed. It was a simple system to operate. When a call was initiated, the user merely dialed the phone number desired after pushing one button to activate the video process. The person on the receiving end could identify a Picturephone call by the ring and a light (red for Picturephone, otherwise white). However, connections between the user and receiver were complex. Two wires were used for the audio portion while another four were used for video. Although three people could be on the camera at a single moment, the 5 X 5 $\frac{1}{2}$-inch screen made it difficult to view standard-sized text and graphs. The test was considered successful since

Westinghouse managers cited significant cost savings related to business travel [Ref. 16:p. 8].

By 1970, Bell Labs still had failed to sell Picturephone to the public; it was simply too expensive for a single resident to consider buying the system for private use. Weak points included rough graphics, a small picture, high production cost, and the fact that it takes two Picturephones to work. Thus AT&T shelved the project in 1973.

As a result of the oil shortage in the early 1970s, transportation costs increased, and alternative methods of travelling and communications were sought. This period started new interest in videoconference technology. Using videoconferencing was more economical than any method of transportation (i.e., it was cheaper to videoconference than to travel by auto or plane).

An early experimental video conferencing system was installed between two locations of Bell Laboratories at Murray Hill, New Jersey, and Holmdel, New Jersey, in 1974 [Ref. 17:p. 312]. Its full-duplex analog TV channel for video teleconference groups was a significant improvement over a strictly audio teleconference.

Today, video teleconferencing is used primarily by private industry and large government organizations. Current videoconference systems generally have the following characteristics.

- Owned by large organizations.
- Large screen, with screens getting bigger.
- Multi-mode, i.e., conference mode, text mode, and graphics mode.
- User operated.
- Involving closed circuit television.

- Black and white, but moving toward full color.
- Interactive, point to point, but moving toward multi-location conferencing.
- Located on premises. [Ref. 15:p. 35]

B. CATEGORIES OF TELECONFERENCING

The functionality and performance required for a teleconferencing system differ greatly depending on the types of input/output information media that are used to share the common space of teleconferencing. Basically, teleconferencing systems have been classified into five categories: audio, audio-graphic, computer, full-bandwidth video, and compressed digital video teleconferencing [Ref. 18:p. 4.124-127]. Table 1 summarizes these types and a comparison of their features. The following sections will include applications, advantages, and disadvantages for each category.

1. Audio Conferencing

The most basic form of conferencing, audio-only, is provided to everyone with a business telephone (see Figure 2). In its simplest form, audio conferencing is a three-way telephone call. When equipped with a speakerphone, an office is transformed into a conference room.

a. Applications of Audio Conferencing

Audio conferencing applications include the following:

- Including remote parties in meetings.
- Remote training.
- General announcements.
- Program management.
- Troubleshooting and equipment maintenance.
- Steering committee meetings. [Ref. 20:p. 18.3]

TABLE 1. CATEGORIES OF TELECONFERENCING
[Ref.19:p. 299]

Systems		Media		Conferencing Terminal	Features
		Basic Media	Optional Media		
Audio conference		Audio	Facsimile	• Speakerphone • Audio conferencing terminal	• Low cost • Conversational capability
Visual	Audio-Graphic	Telewriting (graph, document)	Still picture	• Telewriting tablet • Freeze-Frame conferencing terminal	• Relatively low cost • Conversational capability
Confe-	Full-Bandwidth Video	One-way video	Audio	• Video conferencing terminal	• Expensive • Drawbacks in conversational capability
rence	Compressed Digital Video	Full-motion video	Telewriting (graph, document)	• Video conferencing terminal	• Expensive • Conversational capability
Computer Conference		Character data	Still picture	• Data terminal	• Low cost • Drawbacks in conversational capability

Dozens of audio conference terminals presently are available. They range from small speakerphones to more advanced systems that include frequency equalization and echo reduction circuitry, applicable both to offices and conference rooms. As Boomstein has noted: "...in its more advanced forms, audio conferencing systems can include thousands of participants at hundreds of sites." [Ref. 20:p. 18.4]

Interconnection between terminals is provided by electronic bridging. Audio bridges can be analog or digital and can include advanced features to aid the conference participants and the service provider. Bridging services may be operator-run; the operator sets up the calls or perhaps only monitors the conference to ensure proper audio levels and quality. Services such as SmartLink Electronic Meeting Service from MultiLink, Lynn,

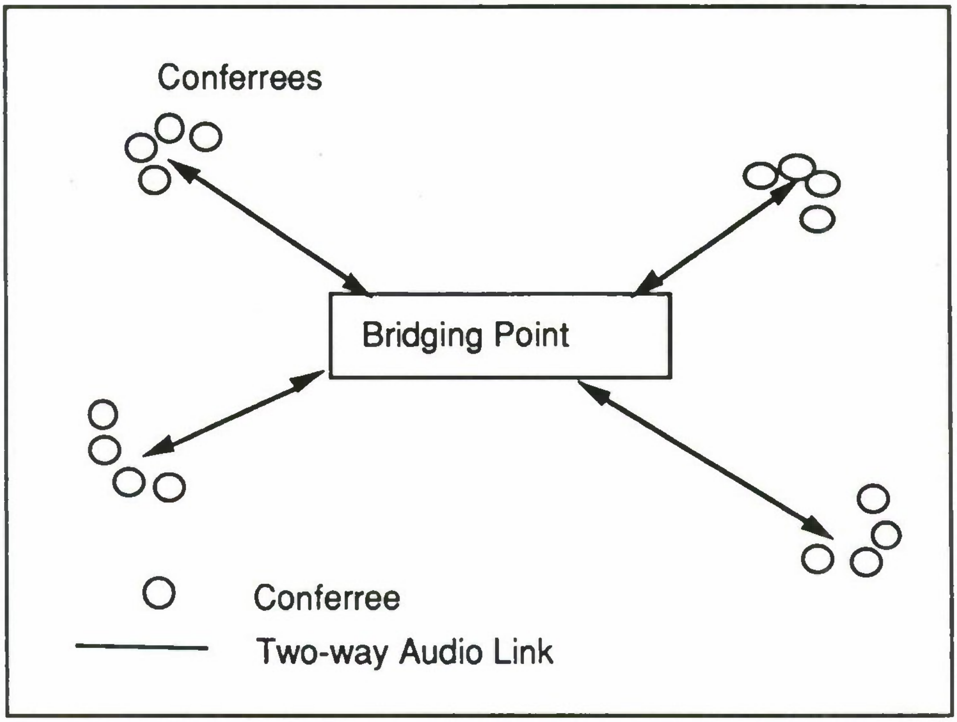

Figure 2. Audio Conferencing
[Ref. 11:p. 14]

Massachusetts, allow up to 40 features. The following are five examples of advanced features.

- *Meet Me.* Everyone attending a meeting can call a predetermined phone number from any phone at the specified meeting time.
- *Subconferencing.* Smaller groups can meet separately and come back into the main meeting at any time simply by touching 0 on their phones and requesting a subconference from the operator.
- *Lecture Mode.* Everyone's talking ability can be cut off except the main speaker for a lecture-type program.
- *Operator Dial-Out.* A missing party can be dialed and added to a conference.
- *Multiple Digital Messages.* User can send more than one messages to more than one absence party. [Ref. 21:p. 10]

b. Advantages and Disadvantages of Audio Conferencing

The advantages of an audio conferencing system are include the following.

- Cost, relative to other teleconference systems, is much lower.
- Easy access to many locations is possible because of the wide distribution of telephones.
- Information is transmitted instantaneously.

The disadvantages are as follows.

- Inability to see the people spoken to or documents spoken about.
- Users can easily be distracted without something visual to focus on (e.g., they may doodle, sign correspondence, etc.).
- Without visual cues, feedback is difficult.
- Good discussions require experience with using the system. [Ref. 22:p. 94]

2. Audio-Graphic Conferencing

Audio conferencing is currently the most convenient way for groups of people to meet, but its lack of visual aids can be limiting. An audio system's effectiveness can be significantly enhanced by adding a graphics component (see Figure 3 below). Sometimes known as enhanced audio conferencing systems, audio-graphics conferences allow users to share typed pages, charts, graphs, diagrams, and even static images of the meeting's participants while they talk [Ref. 23:p. 46]. As with audio conferencing systems, interconnections between terminals are provided by electronic bridging.

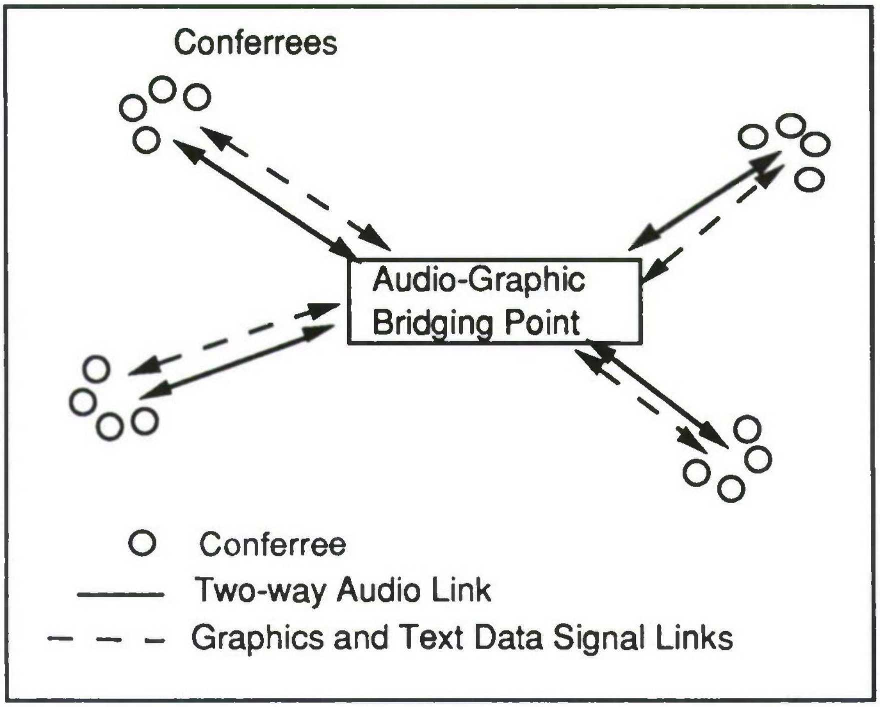

Figure 3. Audio-Graphic Conferencing
[Ref. 11:p. 15]

a. Captured-Frame Video

Several types of visual transmissions for audio-graphic conferencing systems exist. These include captured-frame video systems, annotation devices, and facsimile systems, as described below. The most widely used audio-graphic visual system is captured-frame video, which may be either *slow-scan* or *freeze-frame*. Both of these systems take their input from a monochrome or color camera and transmit the signal for a complete frame in about 1-minute time. A tradeoff exists between image resolution and transmission time. Generally, the better the resolution, the longer the transmission time. When transmission times are less than a minute and

higher resolution in used (e.g., 256 pixels by 512 lines versus 256 by 256), 56 kbps data circuits are then required. [Ref. 20:p. 18.4]

Slow-scan systems were developed first. As technology advanced, freeze-frame systems were introduced in the early 1980s. Freeze-frame systems store the camera signal from a complete frame in a frame memory before transmission. The signal is also stored at the receiver terminal and can be scanned out repeatedly at normal television rates, thus elimination the fading of the picture which was characteristic of slow-scan systems. Freeze-frame also eliminates the distortion or fuzziness of slow scan, caused by camera or subject motion [Ref. 23:p. 46]. The freeze-frame systems can provide one-way static video and two-way audio capability.

b. *Annotation Devices*

Annotation devices generate television signals for the transmission of symbols or line drawings. AT&T uses an electronic board (analogous to a standard blackboard) for the system, to transmit the visual drawings over telephone lines. Currently electronic writeboards, called whiteboards by Japanese, are offered by AT&T, NEC, Panafax, and Okidata Corporations. The *Telewriter* of Optel Communications Corporation is composed of a 5 X 7-inch writing tablet and a transceiver. When a user writes or draws images on the tablet, these are displayed in real time on the receiver site monitor. [Ref. 20:p. 18.5]

c. *Facsimile*

Facsimile systems, known as *fax machines*, optically scan images as with a television camera and convert the scanned image into electrical signals that can be transmitted over telephone or data lines. Fax is one of the

fastest and most reliable methods of transmitting letters and business graphics, and these machines now are standard pieces of office equipment. Early fax systems suffered from poor resolution, extended transmission time, and lack of system automation. The tradeoff between resolution and transmission time remains, but document and paper handling has been automated so that overnight transmission is practical. Table 2 provides the transmission standard for facsimile as set by Consultative Committee of International Telegraph and Telephone (CCITT). [Ref. 20:p. 18.5]

TABLE 2. CCITT STANDARD FOR FACSIMILE SYSTEMS
[Ref. 20:p. 18.5]

CCITT Group	Type of Transmission	Time per page
I	Analog	4-6 min.
II	Analog	2-3 min.
III	Digital	15-19 sec.
IV	Digital	1-5 sec.

d. Applications of Audio-Graphic Conferencing

Audio-graphic conferencing applications include the following.

- Transmission of printed documents and diagrams by facsimile for references.
- Transmission of real time drawings or still image for visual aids.
- Signalling to provide automatic speaker identification; a lamp on a loudspeaker allocated to a specific speaker is activated when that person speaks [Ref. 11:p. 36].
- Remote control of random access slide projectors and microfilm projectors at any or all sites; to call up an image, the speaker uses a regular push-button telephone to key in the two-digit number assigned to the image [Ref. 11:p. 35].

e. *Advantages and Disadvantages of Audio-Graphic Conferencing*

The chief advantages of audio-graphic conferencing are as follows.

- Visual information is transmitted at a relative low cost.
- The narrow bandwidth required enables the use of existing telephone lines.
- The ability exists to ensure that users communicate exactly what they want to transmit.
- Immediate feedback is available if desired.

The disadvantages of these systems are as follows.

- Special equipment is required.
- Dynamic visual cues are absent.
- Screen-only information lacks the richness of information obtained when vision is coupled with the other senses. [Ref. 22:p. 98]

3. Computer Conferencing

Computer conferencing, sometimes known as electronic messaging, involves the use of various kinds of computers for the exchange of data in the form of typed text between participants (see Figure 4 below). No voice communication is used. Computer conferencing is widespread and generally can be initiated by anyone with a personal computer and a modem. For example, acting as an open electronic bulletin board on the Naval Postgraduate School campus, the Apple bulletin board system can keep students up to date on events and issues [Ref. 20:p.18.3]. The computer systems which provide computer conferencing capability usually are known as "host" computers. Users generally must have permission to use a host computer in order to gain access to conferencing facilities. Information is transmitted in

the form of text or other data files between host computers. Thus only digital-transmissions are possible.

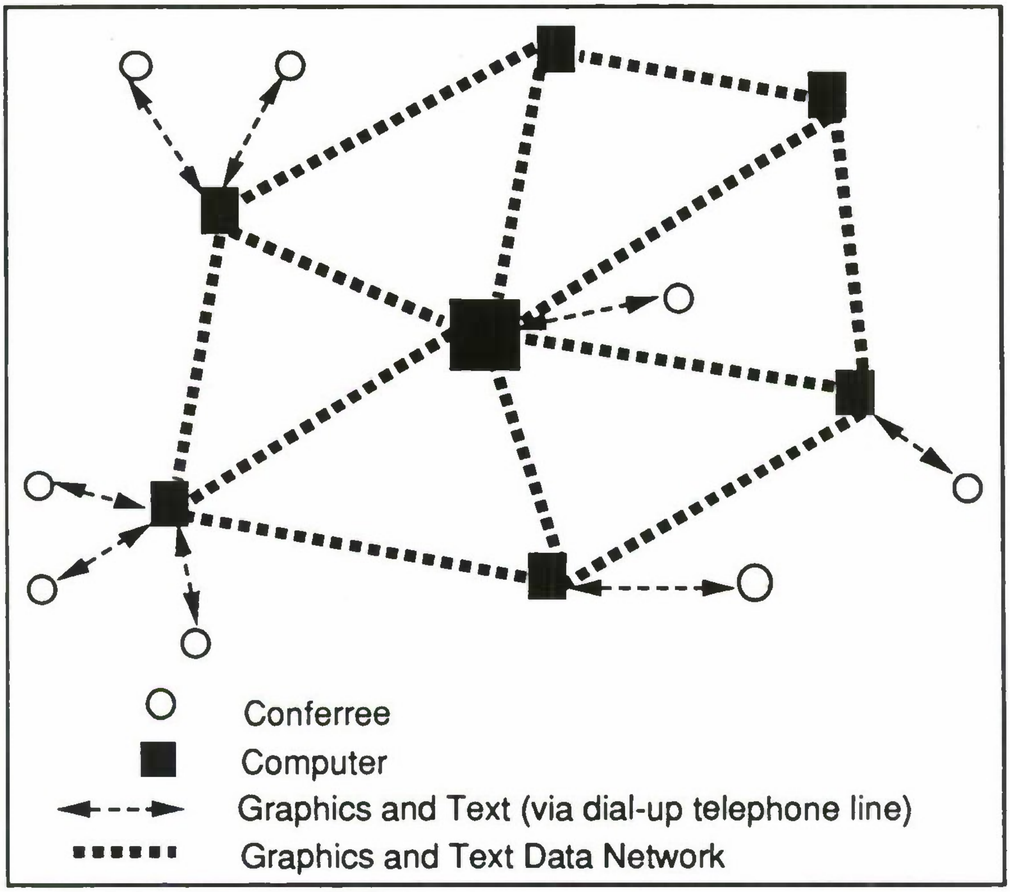

Figure 4. Computer Conferencing
[Ref. 11:p. 14]

a. Applications of Computer Conferencing

Applications of computer conferencing include following.

- Electronic mail and messaging.
- On-line bulletin boards.
- On-line newsletters and journals.
- Long distance file and data transfers.
- On-line meetings that include numerous participants.
- Management conferencing and progress tracking.

- Status and control functions for computer system management.
- Personal "notepad" and work areas for users, on their host computers. [Ref. 44:p. 45]

b. *Advantages and Disadvantages of Computer Conferencing*

The chief advantages of computer conferencing are as follows.

- Asynchronous communications are possible.
- Data are transmitted at a relatively low cost.
- Systems have higher capacity than dedicated communications lines have.
- Higher transmission rates are possible for data, files, records, and programs.
- The narrow bandwidth required enables the use of existing telephone lines.
- Learning is self-paced.
- Time is allowed for thought in work and management.
- Higher selectivity of hard copy references is possible.
- No acting or performing skills are required.

The disadvantages of these systems are as follows.

- Special kinds of equipment are required such as a computer, modem, and printer.
- Users may require an account number at computer network host.
- Higher data redundancy and a lower information rate accompany computer conferencing.
- Real-time conferences are limited in level and scale.
- Typing, instead of speaking, slows down the communication process and feedback.
- Auditory cues are absent.
- Sight-only information lacks the richness of information obtained when vision is coupled with the other senses.
- Eye fatigue can result.
- There is lack of privacy while using bulletin board systems. [Ref. 44:p. 47]

4. Video Conferencing

While either audio or visual communications alone can be valuable for teleconferencing, the combination of the two through video conferencing offers the most promise as a communication tool in information sharing [Ref. 24:p. 30]. These systems permit the users to view real-time dynamic images of each other, while also conversing. *Full-bandwidth analog video* and *compressed digital video* are two kinds of video conferencing methods.

a. *Full-Bandwidth Analog Video (One-Way)*

Full-bandwidth analog video conferencing provides the best visual quality of all existing teleconferencing methods (see Figure 5). The signal requires 4 MHz of bandwidth, the full capacity of a microwave channel or satellite transponder. Transmission also is expensive. This technique most often is used for communicating a special event to large groups of people at widely scattered sites; hence it is sometimes described as "ad hoc video." Similar to the freeze-frame version of captured-frame video, it can provide one-way dynamic video and two-way audio capability. Thus viewers at remote sites can interject comments and ask questions, while visually observing participants in a conference.

Satellites are the most common transmission medium for full-bandwidth teleconferencing. By transmitting to a large number of sites, the cost per site is reduced. Since full-bandwidth teleconferencing is intended to present information to an audience rather than for audience participation, ad hoc conferences tend to be staged as events [Ref. 20:p. 18.6]. Analog video conferences are usually professional presentations and thus usually entail

high production costs. The average analog video conference costs in excess of $100,000 to produce.

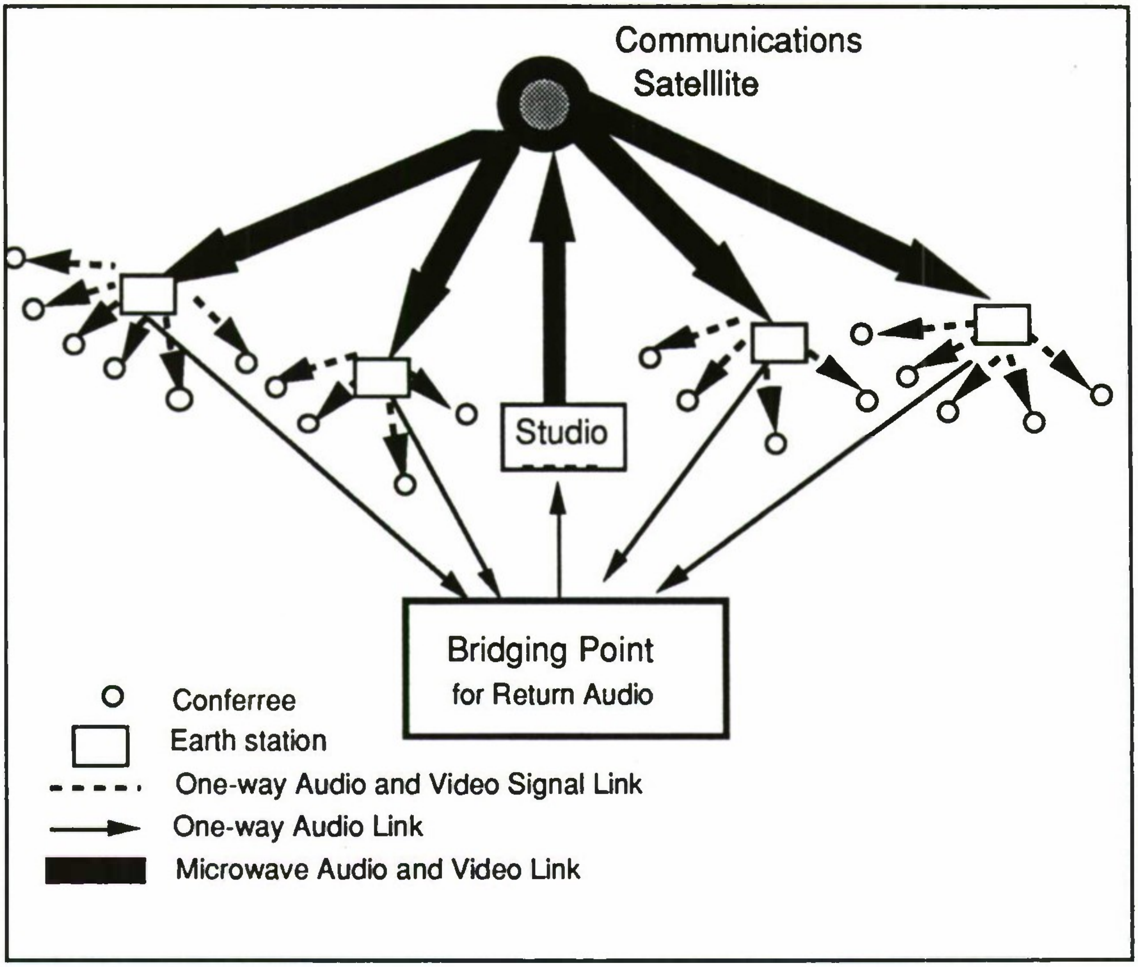

Figure 5. Full-Bandwidth Analog Video (One-Way)
[Ref.11:p. 14]

Full-bandwidth, one-way analog video continues to grow in popularity because of its ability to reach large groups of people in an efficient and economical manner. Its main drawback is its inability to provide cost-effective full interactive communications.

b. Compressed Digital Video (Two-Way)

Most people associate two-way full-motion video conferencing with the term *teleconferencing* (see Figure 6). These systems allow users on both ends to see dynamic images of each other while conversing as if they were face to face. Currently the most advanced mode of teleconferencing, the majority of digital video compression systems are "full feature." This is, they include two-way interactive dynamic motion video signals, audio signals synchronized with the video, and some form of graphics imaging [Ref. 25:p. 345]. To reduce transmission costs, the video signals are converted to digital form and compressed in bandwidth then transmitted as digital signals or via satellite. Multipoint video, usually in the form of a three-way conference, is becoming prevalent.

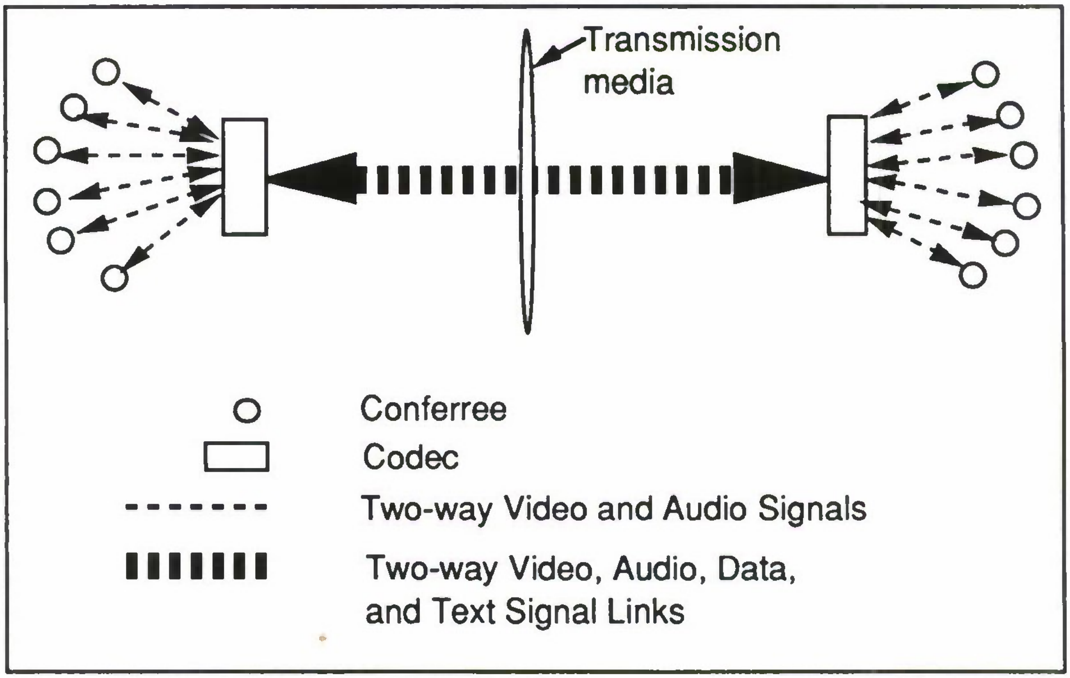

Figure 6. Compressed Digital Video (Two-Way)Conferencing [Ref. 11:p. 15]

The major difference between full-bandwidth analog (one-way) and compressed digital (two-way) conferencing results from devices called coder-decoders, or codecs (see Figure 7). Codecs entered service in mid-1981. These devices are the functional inverse of modems: a modem converts a digital bit stream into a modulated analog signal; a codec converts a continuous analog signal into a digital bit stream. These systems convert analog video signals into a digital bit stream and compress the signal bandwidth by a ratio of 30 : 1, from 90 Megabits per second (Mbps) to 3 Mbps. As a result, point-to-point transmission costs are on the order of 1% of the cost of uncompressed broadcast signals. However, the limited availability and cost of 3-Mbps circuits made them impractical for most corporations in the early 1980s.

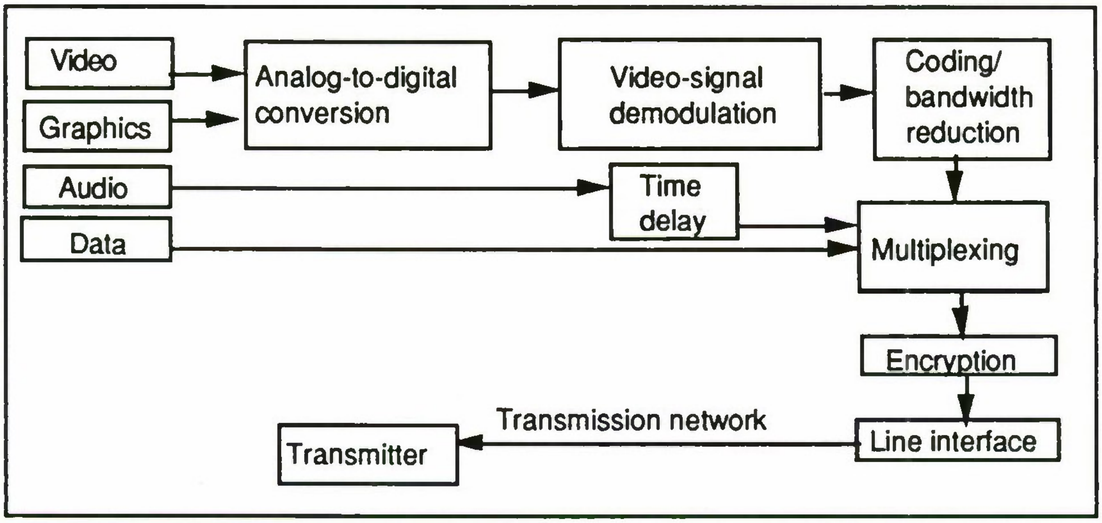

Figure 7. Functional Diagram of Video Codec
[Ref. 20:p. 18.8]

In April 1982, Compression Labs, Inc., first introduced full-motion codecs which could digitally compress analog video signals into a bandwidth of 1.5 Mbps. Two-way video teleconferencing became practical

because these signals could be transmitted on standard T1 carriers, digital communications circuits capable of transmitting digital information at 1.544 Mbps, which serve as the basic transmission channel of public telephone systems. [Ref. 20:p. 18.7]

Capital costs also fell. Codecs, which ranged in cost from $150,000 to $175,000 in 1982, fell to $60,000 to $85,000 in 1987. In 1989 a system costs between $30,000 and $68,000, and prices are still dropping. [Ref. 26]

There are three primary manufacturers of codecs which operate in the 384 kilobits per second (kbps) to 1.544-Mbps range. They are Compression Labs, Inc. (CLI), in the United States, GEC Video Systems in the United Kingdom, and Nippon Electric Corporation (NEC) in Japan [Ref. 27]. Codecs can convert signals from the North American National Television System Committee (NTSC) system to the European phase-alternating line (PAL) system or vice versa at either the transmit or receive end. The transmission rates for the various products are shown in Table 3.

TABLE 3. TRANSMISSION RATES AND PRODUCERS OF CODECS
[Ref. 20:p. 18.7]

Codec	Transmission rates
CLI	384 kbs-3.136 Mbs
GEC	768 kbs-2.046 Mbs
NEC	512 kbs-6.0 Mbs

Another class of codecs, narrowband systems which operate in multiples of 56 kbps or 64 kbps, was introduced in the late 1980s. Their dynamic properties (often called motion-handling capability) are in some respects superior to those of their wideband counterparts. However, picture

resolution is usually about half that of the wideband systems [Ref. 28]. CLI and PictureTel are two major producers of 56-kbps codecs in the United States. Both manufacturers make full-featured systems, designed to take advantage of switched 56-kbps networks for use with desktop terminals. Prices range from $45,000 to $68,000 per pair. Products made by OKI, a Japanese producer, cost less, ranging from $30,000 to $40,000 per pair [Ref. 27].

The codec is designed to accept the numerous types of signals that a full feature video conference requires. Inputs include one or more full-motion video signals for transmitting images of the conferees, audio signals which are synchronized with the video, a video input for displaying graphics, and user data signals. Most codecs employ some type of error-correcting code to reduce errors that may be caused by the transmission medium. If security is required, the bit stream is encrypted prior to transmission.

Video compression involves an inherent tradeoff between picture resolution and motion-handling capability. Picture quality depends on the transmission bandwidth. As the bandwidth is reduced, more encoding is required and picture quality is poorer. [Ref. 20:p. 18.8]

Graphics are usually presented in static form. To send a graphic, the user utilizes the codec to send an image signal which is compressed in the same fashion as full-motion signals. Graphics interleaving results in interruption or freezing of the motion video for a period of 0.5 to 1.5 seconds, depending on the complexity of the graphics image and the transmission bandwidth. [Ref. 20:p. 18.9]

Audio signals may also go through a bandwidth-reduction stage, as they are processed through time-delay circuitry to be synchronized with the

video signals. User data signals already are in digital form and thus, are transmitted without any conversion. These signals range from information exchanges between personal computers to data used by room coordinators for the conference facilities.

Video conferencing is well-suited to digital compression technology, since the typical video conference scene consists of four to six people seated at a table. Unless a speaker is making a stand-up presentation at a chalkboard, giving a demonstration, or showing a videotape, image motion is limited to small areas of the total picture. Most codecs provide video quality which is more that adequate for this application. Equipment costs range from $70,000 to over $500,000 for a complete videoconferencing facility, with most facilities costing about $125,000 for a single facility. [Ref. 29]

c. *Applications of Videoconferencing*

Popular applications of videoconferencing are as follows.

- Executive briefings and board meetings.
- Project management meetings.
- Product development conferences.
- Financial planning seminars.
- Product announcements and press conferences.
- Sales presentations to customers.
- Training and demonstrations.
- Lectures and seminars.
- Personnel interviews.
- Operations monitoring.
- Real-time reporting during a crisis. [Ref. 26]

d. *Advantages and Disadvantages of Videoconferencing*

The advantages of videoconferencing are as follows.

- Face-to-face communications may not be necessary.
- Enough information is transmitted to facilitate complete communications.
- Short, task-oriented, goal-oriented meetings are conducted effectively and efficiently (e.g., decision making meetings, demonstrations, training courses, etc.).

The disadvantages of videoconferencing are as follows.

- Cost is the highest among all kinds of teleconferencing.
- Conferees require some basic training or a facilitator to facilitate a meeting.
- It may be difficult for conferees to relax, since they may feel they must "perform."

C. MEDIA USED FOR TELECONFERENCE SYSTEM TRANSMISSION

Signals can be transmitted over a number of teleconferencing media ranging from copper wires to complex satellite networks. This section describes the various media that are in use for this purpose.

1. Guided Media

Guided media include twisted pair wires, coaxial cable, and fiber optics. Table 4 compares the transmission characteristics of these guided media. Their attenuation rates are compared in Figure 8 .

a. Twisted Pair Wires

Copper and other metallic wires offer the lowest-cost transmission medium for short distances. Wires may be used for voice and data communications, but not for video transmission as video requires a much greater bandwidth than wires provide. Twisting of the wires reduces electromagnetic interference between the pairs, thus reducing crosstalk. Each

TABLE 4. POINT-TO-POINT TRANSMISSION CHARACTERISTICS OF GUIDED MEDIA
[Ref. 30:p. 47]

Transmission Medium	Total Data Rate	Bandwidth	Repeater Spacing
Twisted pair	4 Mbps	250 kHz	2-10 km
Coaxial cable	500 Mbps	350 MHz	1-10 km
Optical fiber	2 Gbps	2 GHz	10-100 km

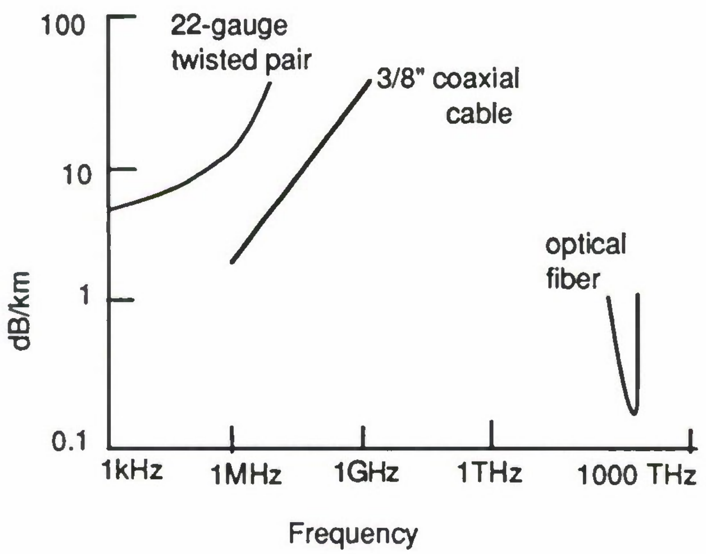

Figure 8. Attenuation of Typical Guided Transmission Media
[Ref. 30:p. 49]

pair of wires employs a constant twist rate, but the twist rate differs between adjacent pairs. The wires in a pair have thicknesses ranging from 0.016 to 0.036 inch [Ref. 30:p. 47]. The capacity of one twisted pair is either 32

simultaneous voice transmissions, or data transmission from eight to 20 computer terminals, if the appropriate hardware is used.

Wire pairs may be used to transmit both analog and digital signals. For analog signals, amplifiers are required about every 5 to 6 km. For digital signals, repeaters are used every 2 or 3 km. Compared to other transmission media, transmission using twisted pair wires is limited in distance, bandwidth, and data rate. Figure 9 shows the achievable data rate versus distance for a common balanced electrical signaling technique, the Electronics Industries Association (EIA) standard RS-422.

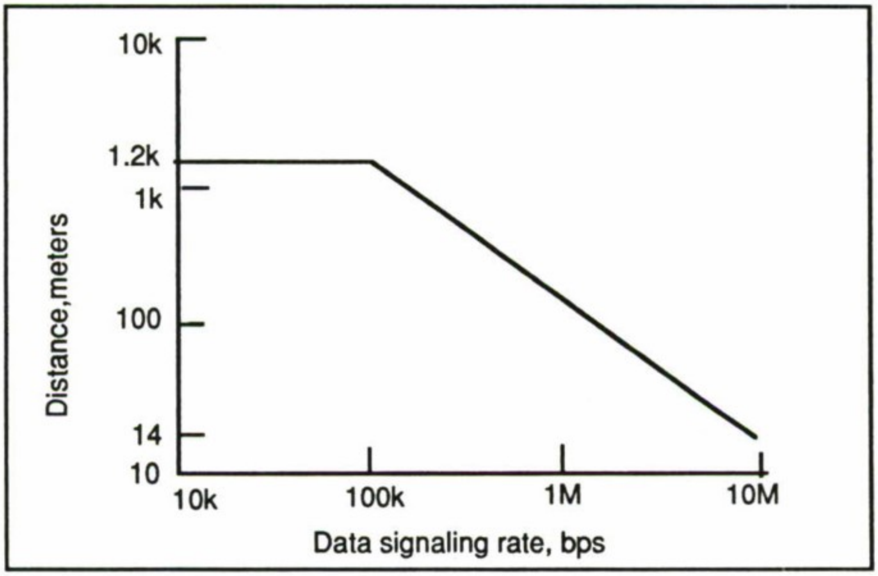

Figure 9. Twisted Pair Cable Length vs. Data Rate
[Ref. 30:p. 50]

By using wires for transmission of point-to-point analog signals, a bandwidth of up to 250 kHz is possible, and for digital point-to-point lines, data rates of up to a 4 Mbps are possible [Ref. 30:p. 49]. For analog voice transmission, such as a local loop which uses direct current (DC) to connect a subscriber to one of the nodes in a network, the attenuation is about 1 dB/km

over the voice frequency range [Ref.30:p. 245]. A shielded twisted pair wires cable, which accommodates 12 pairs of wires, costs only about $1.40 per foot [Ref. 31:p. 20]. As a transmission medium for teleconferencing, twisted pair wires can be used for audio conferencing, audio-graphics conferencing, and computer conferencing.

b. Coaxial Cable

Coaxial cable, like twisted pair wires, consists of two conductors. However, it is constructed differently to permit it to operate over a wider range of frequencies. These cables consist of a hollow outer cylindrical conductor which surrounds a single inner wire conductor. The inner conductor can be either solid or stranded; the outer conductor can be either solid or braided. A single coaxial cable has a diameter of from 0.4 to about 1 inch. Coaxial cable has frequency characteristics that are superior to those of twisted pair wires, and can hence be used effectively at higher frequencies and data rates. Cables can transmit 130,000 times more data at 100 times the rate of conventional twisted pairs wires. [Ref. 31:p. 19]

Coaxial cable is perhaps the most versatile transmission medium and is enjoying increasing utilization in a wide variety of applications. The most important of these are:

- Long-distance telephone and television transmission.
- Short-distance cable television distribution.
- Local area networks.
- Short-run system links. [Ref. 30:p. 50]

Because of its shielded, concentric construction, coaxial cable is much less susceptible to interference and crosstalk than are twisted pair wires [Ref. 30:p. 51]. The principle constraints on performance are attenuation,

thermal noise, and intermodulation noise. For long-distance transmission of analog signals, known as broadband signals, amplifiers are needed every few kilometers, with closer spacing required if higher frequencies are used (see Figure 10). The usable spectrum for analog signaling extends from 300 Hz to about 400 MHz; it is suitable for transmission of voice, data, and video signals. Speeds range from 20 to 50 Mbps. For digital signaling, i.e., baseband signaling, speeds range from 1 to 50 Mbps, and repeaters are needed every kilometer or so, with closer spacing needed for higher data rates. [Ref. 32:p. 407]

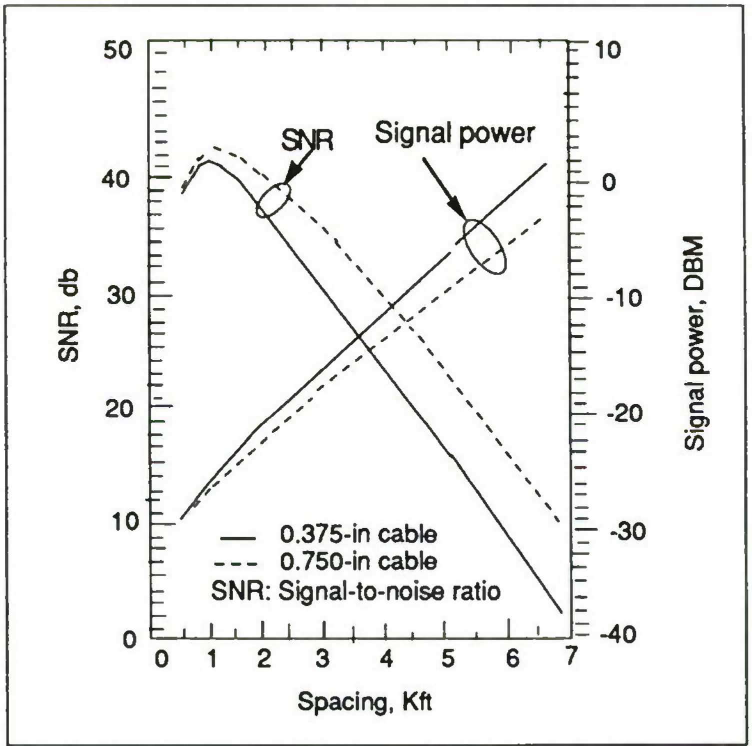

Figure 10. Coaxial Cable Spacing Versus Signal Power (Using 1.5 MHz Bandwidth)
[Ref. 30:p. 52]

Coaxial cables are usually used in applications requiring higher data rates or greater shielding than twisted pair wires can provide. Coaxial

cable costs from $1 to $9 per foot. As a transmission medium for teleconferencing, coaxial cable can be used for audio conferences, audio-graphics transmissions, and video conferencing.

c. *Optical Fiber*

An optical fiber is a thin (2 to 125 μm), flexible medium capable of conducting an optical ray. Various glasses and plastics can be used to make optical fiber [Ref. 33:p. 85]. Lowest transmission signal losses have been obtained using fibers of ultrapure fused silica. Ultrapure fiber is difficult to manufacture; higher-loss multicomponent glass fibers are more economical and still provide good performance.

An optical fiber cable has a cylindrical shape and consists of three concentric sections: the core, the cladding, and the jacket. The core is the innermost section, and consists of one or more very thin fibers made of glass or plastic. Each fiber is surrounded by its own cladding, a glass or plastic coating that has optical properties different from those of the core. The outermost layer, surrounding one or a bundle of cladded fibers, is the jacket. The jacket is composed of plastic and other materials layered to protect against moisture, abrasion, crushing, and other environmental dangers. [Ref. 30:p. 53]

The following characteristics distinguish optical fiber from twisted pair wires and coaxial cable.

- Greater Bandwidth: a 2 Giga bits per second (Gbps) data rate has been demonstrated over tens of kilometers for optical fiber media. This compares to about 500 Mbps over about 1 km distance for coaxial cable and about 4 Mbps over 1 km for twisted pair wires.
- Smaller size and lighter weight: optical fibers are at least an order of magnitude smaller in diameter than coaxial cable or twisted pairs for comparable data transmission capacity.

- Lower attenuation: attenuation is significantly lower for optical fiber than for coaxial cable or twisted pair wires, and is constant over a wide range.
- Electromagnetic isolation: optical fibers are not affected by external electromagnetic fields [Ref. 34:p. 27].
- Greater repeater spacing: fewer repeater stations are needed, yielding lower cost and fewer sources of error. Bell Labs has successfully tested a 68-km repeaterless link at 8 Gbps with a bit error rate of 3×10^{10} [Ref. 35:p. 48]. Coaxial and twisted pair systems generally require repeaters every few kilometers.

Optical fiber transmits a signal-encoded beam of light by means of total internal reflection. Total internal reflection can occur in any transparent medium that has a higher index of refraction than the surrounding medium. The optical fiber acts as a waveguide for frequencies in the range 10^{14} to 10^{15} Hz (wavelength range from 3000 nm to 300 nm), which covers the visible spectrum and part of the infrared spectrum.

There are three basic types of optical fiber, as illustrated in Figure 11 and compared in Table 5. Multimode fibers are divided into step-index and graded-index fiber. Using theses fibers, rays travelling at shallow angles are reflected and propagated along the fiber; other refracted rays are absorbed by the surrounding material. Single mode fiber takes advantage of the fact that when radius of fiber is reduced, rays travelling at fewer angles will reflect. By reducing the radius of the core to the order of a single wavelength, rays travelling at only a single angle or mode can pass. [Ref. 30:p. 55]

Both single mode and multimode fibers can support several different wavelengths of light and can employ laser or light-emitting-diode (LED) light sources. There is a relationship among the wavelength employed, the type of transmission, and the achievable data rate [Ref. 36:p. 56]. In optical

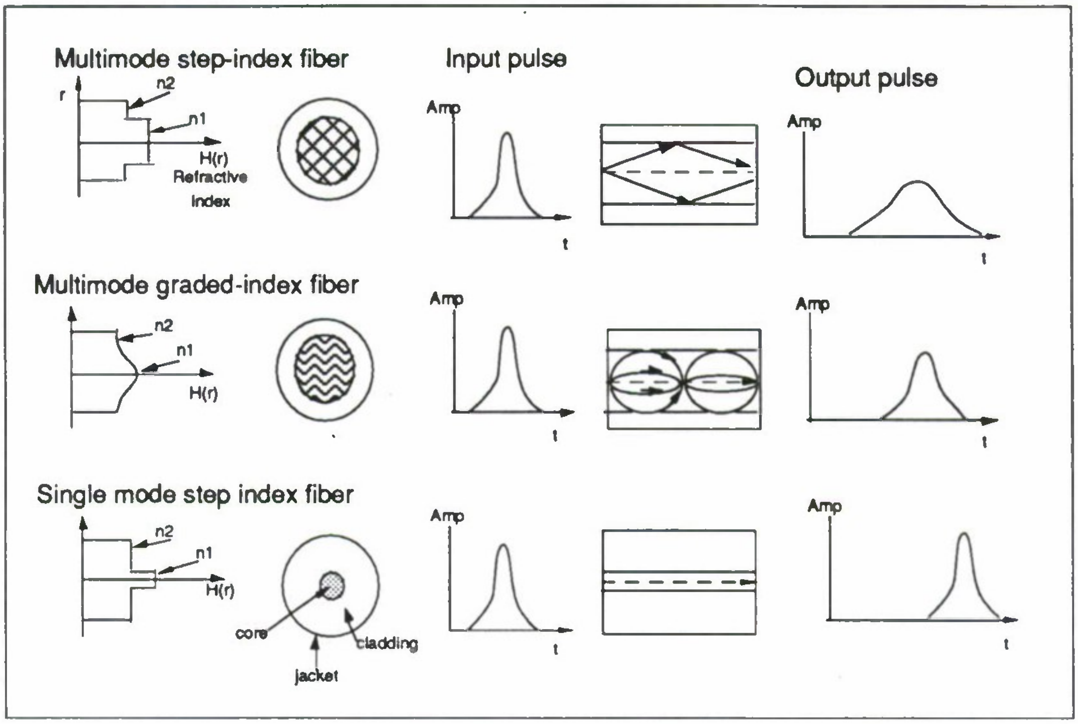

Figure 11. Optical Fiber Transmission Modes
[Ref. 30:p. 55]

fiber, light propagates best in three distinct wavelength "windows," centered on 850, 1300, and 1500 nm. These are all in the infrared portion of the frequency spectrum, below the visible-light portion, which is from 400 to 700 nm. Most local area applications today use 850-nm LED light sources. Although this combination is relatively inexpensive, it is generally limited to data rates under 100 Mbps and distances of a few kilometers. To achieve higher data rates and longer distances, a 1300-nm LED or laser source is needed. The highest data rates and longest distances require 1500-nm laser sources. [Ref. 37:p. 326]

A pair of glass fibers can carry 1300 ordinary voice conversations simultaneously, using one fiber for transmission and the other for receiving. A 1.5-pound fiber optic cable can transmit the same amount of data as 30

pounds of copper wire. Compared to an ordinary coaxial cable, which can carry more than 5000 voice channels, a single fiber optic cable can carry as many as 50,000 channels [Ref. 32:p. 407]. Optical fiber transmission media can be applied to audio conferences, audio-graphic transmissions, computer conferences, and video conferencing.

TABLE 5. COMPARISON OF THREE TYPES OF OPTICAL FIBERS
[Ref. 30:p. 56]

	Step-Index Multimode	Graded-Index Multimode	Single-Mode
Light Source	LED/laser	LED/laser	laser
Bandwidth	200 MHz/km	200 MHz-3 GHz/km	3 GHz-50 GHz/km
Typical Application	Computer Data Link	Moderate-length telephone lines	Telecommunication long lines
Cost	least	more	most
Core Diameter (μm)	50 -100	50 - 125	2 - 8
Cladding Diameter (μm)	125 - 440	125 - 440	15 -60
Attenuation (db/km)	10 -50	7 - 15	0.2 - 2
Pulse Dispersion	Hi	Med	Low

2. Unguided Media

Table 6 provides detailed information on the characteristics of and applications for the various unguided communications frequency bands. There are two major ways of using unguided media to communicate; these are terrestrial microwave transmission for short links, and satellite transmission for long links.

TABLE 6. CHARACTERISTICS OF UNGUIDED COMMUNICATIONS FREQUENCY BANDS

[Ref. 30:p. 48]

Frequency Band	Analog		Digital		Applicatons
	Modulation	Bandwidth	Modulation	Data Rate	
30-300 kHz (LF)			ASK, FSK, MSK	0.1-100 bps	Navigation
300-3000 kHz (MF)	AM	to 4 kHz	ASK, FSK, MSK	10-1000 bps	Commercial AM radio
3-30 MHz (HF)	AM, SSB	to 4 kHz	ASK, FSK, MSK	10-3000 bps	Shortwave radio
30-300 MHz (VHF)	AM, SSB; FM	5 kHz-5 MHz	FSK, PSK	to 100 kbps	VHF Television FM radio
300-3000 MHz (UHF)	FM, SSB	to 20 MHz	PSK	to 10 Mbps	UHF Television Terrestrial microwave
3-30 GHz (SHF)	FM	to 500 MHz	PSK	to 100 Mbps	Terrestrial microwave Satellite microwave
30-300 GHz (EHF)	FM	to 1 GHz	PSK	to 750 Mbps	Experimental short Point-to-point

LF: low frequency, MF: medium frequency, HF: high frequency, VHF: very high frequency,
UHF: ultra high frequency, SHF: super high frequency, EHF: extremely high frequency.
FM: frequency modulation, AM: amplitude modulation, SSB: single side band.
ASK: amplitude shift key, FSK: frequency shift key, MSK: minimum shift key, PSK: phase shift key.

a. *Terrestrial Microwave Systems*

The most common type of terrestrial microwave antenna (transceiver) for transmitting and receiving is the parabolic dish. A typical dish is about 10 ft in diameter. The antenna is fixed rigidly and focuses a narrow beam to achieve line-of-sight (LOS) transmission to the receiving antenna (see Figure 12).

Terrestrial microwave systems can attain speeds of 50,000 characters per second or even higher. These systems involve transmission stations sending data through the air as coded signals [Ref. 32:p. 407]. Relay stations or towers approximately 30 miles apart contain devices that receive and transmit data to other stations. If the stations are obstructed by

geographical features that block the signals or if the data must be transmitted over the curvature of the earth, the signals are often relayed through orbiting satellites. Due to the increasing cost of establishing ordinary wire communication lines, microwave transmission is being used more and more as an alternative to coaxial cable for transmitting television and voice signals. Microwave facilities require far fewer amplifiers or repeaters than coaxial cable for the same distance, but require LOS transmission.

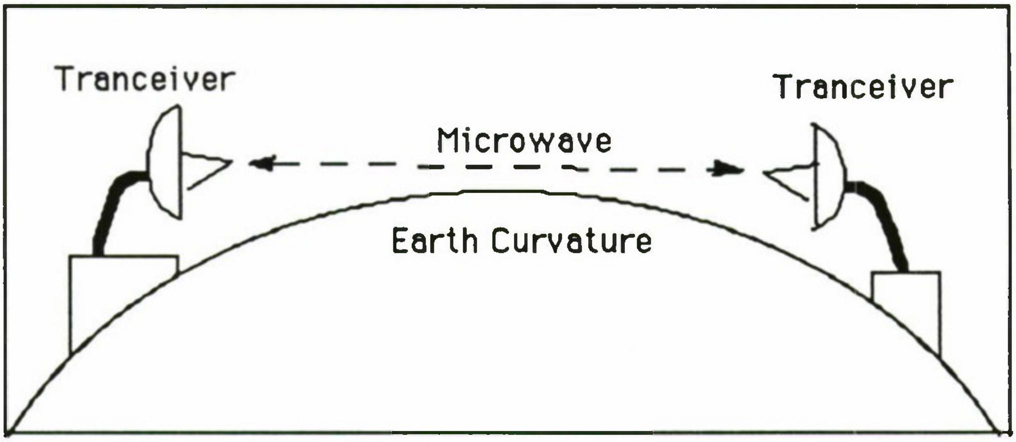

Figure 12. Terrestrial Microwave
[Ref. 20:p. 4.4]

An increasingly common use of microwave transmissions is for short point-to-point links between buildings, such as for closed-circuit TV or as a data link between local area networks (LAN) [Ref. 37:p. 56]. Because terrestrial microwave systems are limited by LOS and the high cost of transceivers, most teleconferencing systems use them as short range transmitters.

The advantages of using terrestrial microwave transmissions are as follows.

- Wideband capability is available.

- They are inherently suited for mobile applications.
- Systems are readily compatible with various new technologies (e.g., digital computers and analog high-definition TV).
- System capabilities are sometimes greater than immediate needs, allowing for growth as necessary.
- Services can be provided directly to the users' premises.

The limitations of terrestrial microwave are as follows.

- High initial investments in transmitter and receiver systems are required.
- Spectrum crowding, frequency sharing, and power flux density all limit system usefulness.
- Maintenance can be difficult, awkward, or expensive. [Ref. 38:p. 10]

b. *Satellite Microwave Systems*

Satellites work as microwave relay stations. The two basic segments of communications satellite systems are space and earth systems (see Figure 13). The space segment includes the satellites, the launch vehicles, and the facilities required to place, maintain, and replace these satellites. This includes ground telemetry, tracking, and control functions. The earth segment includes earth stations with their antennas, radio frequency (RF) amplifiers, modulation/demodulation, and baseband equipment [Ref. 38:p. 8]. After a satellite receives transmissions on one frequency band (uplink), it amplifies (analog transmission) or repeats (digital transmission) the signal, and transmits it on another frequency (downlink). Two satellites using the same frequency band, if close enough together, will interface with each other. To avoid this, current standards require 4 degree spacing in the 4 to 6-GHz band, and 3 degree spacing in the 12 to 14-GHz band. Thus the possible number of satellites is quite limited [Ref. 30:p. 59].

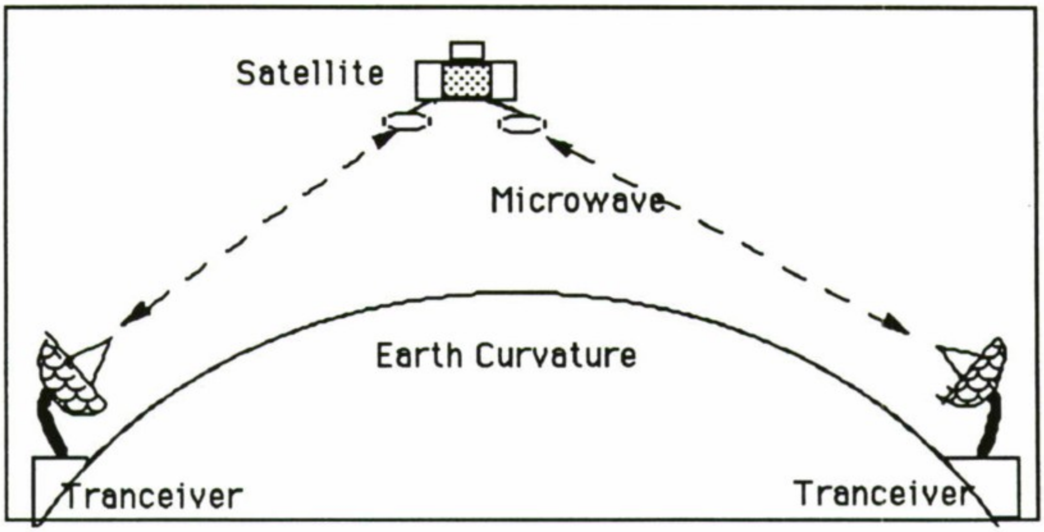

Figure 13. Satellite Microwave Communications
[Ref. 20:p. 5.2]

Development of the communication satellite has been a technological revolution as important as fiber optic technology. Satellites are particularly useful for long-distance communications services, for services across oceans or difficult terrain, and for point-to-multipoint services such as television distribution [Ref. 39:p. 84]. Satellites provide the optimum media for broadcast and high-usage international trunks. They are competitive with terrestrial microwave and coaxial cable for many long-distance international links [Ref. 30:p. 60]. Half of the video networks for teleconferencing in U.S. are using satellite transmission, primarily for long haul applications [Ref. 40:p. 26].

The optimum frequency range for satellite transmission is in the range from 1 to 10 GHz. Below 1 GHz, there is significant noise from natural sources, including galactic, solar, and atmospheric noise, and human-made noise from various electronic devices. Above 10 GHz, the signal is severely attenuated by atmospheric absorption and precipitation. Because of the long

distances involved, there is a propagation delay of about 240 to 300 ms for transmission between earth stations. This delay is not only noticeable in ordinary telephone conversations but also introduces problems in the areas of error control and flow control [Ref. 38:p. 254].

The cost of an earth station capable of both transmitting and receiving signals is approximately $70,000. Each satellite costs millions of dollars to build and place into orbit. Because satellite capacity is limited by bandwidth, there is great competition for access to the facilities. Lease costs for a transponder on a satellite (capable of supporting the equivalent of 1000 telephone lines) begin at about $13 million per year. A single 56 kbps circuit costs at least $10,000 per month. [Ref. 31:p. 32]

The advantages of using satellite transmissions over the other media are as follows.

- Satellite systems have wideband capability to transmit video, audio, and data signals.
- Wide area coverage by satellite system is readily possible.
- Satellite systems are distance-insensitive to transmission costs.
- Satellite systems have a counterinflationary cost history.
- All users of satellite systems have same access possibilities in spite of their sizes and locations.
- Point-to-point, point-to-multipoint (broadcast), and multipoint-to-point (data collection) are all possible by using satellite systems.
- Satellite systems are inherently suited for mobile applications.
- Satellite systems are readily compatible with new technology (e.g., digital computers and analog high definition TV).
- Satellite systems can provide services directly to the users' premises.

The limitations of satellite transmissions are as follows.

- High initial investments in space segment of satellite systems are required.

- Using satellite systems, new investments may be required for earth stations.
- Satellite lifetimes are short (7-10 years).
- Satellite systems have some limits such as orbit/spectrum crowding, frequency sharing, power flux density .
- End user access to satellite systems may be difficult for engineering or regulatory reasons.
- Institutional/legal/regulatory aspects may have some limits for satellite systems.
- Maintaining a satellite system maybe difficult, awkward, or expensive.
- Launch vehicle reliability is not very high. [Ref. 38:p. 10]

3. Comparison of Media Used for Teleconferencing

The factors affecting choice of a transmission medium will vary greatly from one situation to another. A large established carrier with numerous existing sites will have different requirements then will a business deciding to build a private system where none exists. Assuming that several media can satisfy the capacity needs and meet the performance standards of teleconferencing, factors such as ability to acquire right-of-way for cables and other equipment may govern the decision.

A useful metric for comparing the performance capabilities of twisted pairs, coaxial cable, and fiber optic cable is the product of transmission bandwidth and range [Ref. 31:p. 31]. The bandwidth-range parameter is 1 MHz per kilometer for common twisted pair wires, 20 MHz per kilometer for coaxial cable, and 400 MHz per kilometer for fiber optic cable. Boss proposes a general cost and performance factor, computed by taking the average cable cost ($1 per foot for twisted pair wires, $3 per foot for coaxial cables, and $1.50 per foot for fiber optic cables) and dividing the bandwidth and range

parameter into the cost per kilometer. This gives the following relationship between the cost per MHz and the bandwidth for one kilometer range:

- Twisted pair wires: $300 per MHz per km.
- Coaxial cables: $450 per MHz per km.
- Fiber optic cables: $10 and up per MHz per km. [Ref. 31:p. 30]

Given a need for high capacity transmissions and great speed over distance, the technology of choice for a teleconferencing system would be fiber optic cable. But within a building, twisted pair wires or coaxial cable would be more cost-effective. Over distances much greater than one kilometer, microwave and fiber optics would be competitive. However, over 500 miles, the requirement for microwave relay stations every 30 miles and fiber optics repeaters every 60 miles grows too expensive, thus satellite transmissions probably would be best [Ref. 31:p. 33]. Based on the rule of thumb proposed by Boss and on other practical considerations, fiber optics and satellite links might be two reasonable alternatives for a 200-mile domestic teleconferencing system in Taiwan.

D. TREND OF TELECONFERENCING

Many studies have been conducted to determine the anticipated teleconferencing market from 1975 to 1992. Olgren, in his 10-year (1975-1985) U.S. trend market analysis, notes: "...Teleconferencing increased significantly from 1975 through 1985, experiencing a net growth of 523%." This 10-year growth figure is based on data from 459 organizations--239 continuing users plus 60 that discontinued teleconferencing during that period [Ref. 40:p. 22]. Some 65% of users started teleconferencing in 1980 or later. Business users grew from 19 companies in 1975 to 81 firms in 1980, and to 212 in 1985, an

increase of more than 1,000%. These firms accounted for 53% of the total teleconferencing market in 1985 (see Figure 14 below).

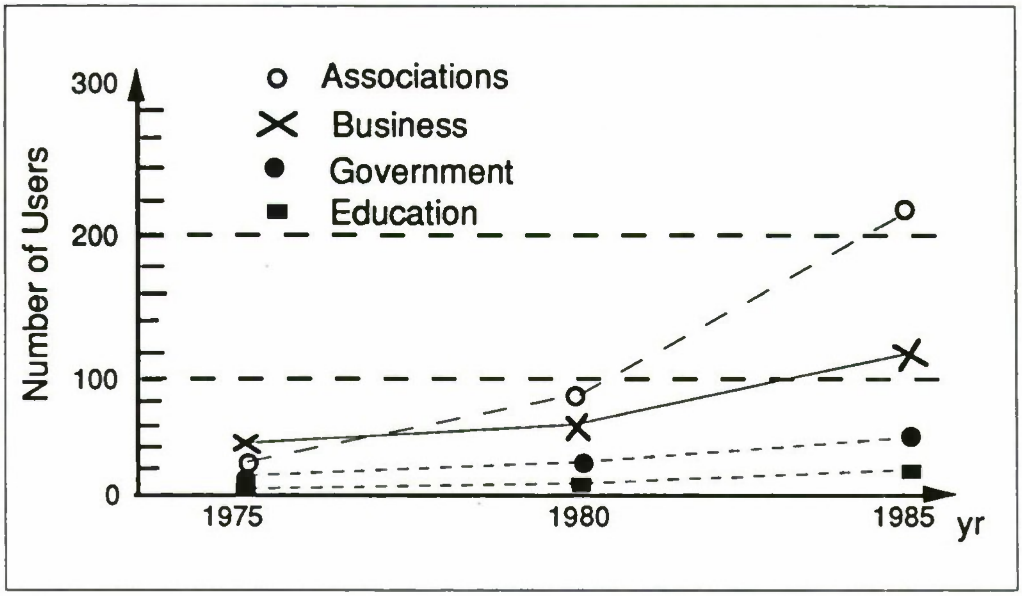

Figure 14. Teleconferencing User Growth
[Ref. 40:p. 23]

The market share of educational institutions dropped from 53%to 29% during the decade. From 34 organizations in 1975, educational teleconferencing systems grew 238% to 115 users in 1985. Government teleconferencing increased 181% from 1976 to 1980; the growth rate then declined to 61% from 1981 to 1985. One of the most active government segments is the US military, which has been installing videoconferencing facilities for its Defense Commercial Telecommunications Network under a $900-million contract. In addition, eight of the top-10 aerospace defense contractors routinely use teleconferencing. [Ref. 40:p. 23]

The 10-year trend in audio conferencing shows that the use of audio systems increased by 170 percent from 1975 to 1981. However, the growth rate slowed to 73 percent from 1981 through 1985, the lowest rate of all types of

teleconferencing. During that time audio systems lost ground to video systems (see Figure 15). [Ref. 40:p. 25]

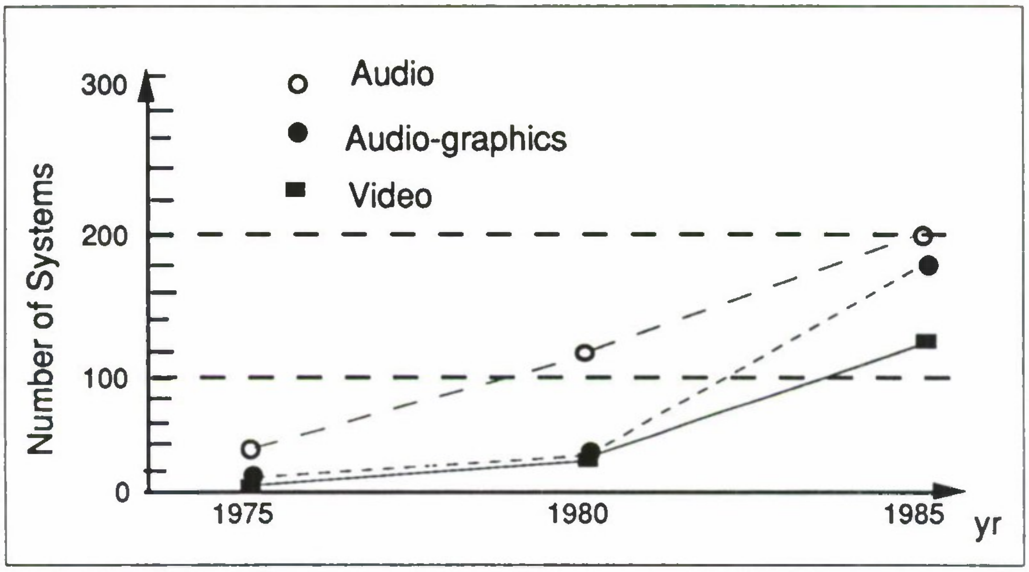

Figure 15. Teleconferencing Systems Growth
[Ref. 40:p. 25]

On the other hand, video conferencing experienced the fastest growth rate of all systems from 1981 through 1985, increasing by 345%. This compares with growth of 150% from 1976 to late 1980. In 1985, 39% of user organizations had at least one video system, versus 20% in late 1980. The video market began to change dramatically after 1981 as codec systems improved performance and decreased costs. The introduction of codec systems for compressed video, followed by the wider availability of T1 transmission circuits, roll-about video cabinets, and declining transmission rates, contributed to reduction of cost of two-way videoconferencing.

From 1975 to 1985, satellite transmission was used in half of the video networks, primarily for long-haul applications. Other systems employed

microwave, coaxial, or fiber optics, mainly for regional or local distribution. [Ref. 40:p. 26]

The University of Wisconsin also conducted a trend market analysis for teleconferencing, covering the years 1984 to 1990. This institution reports that, the early 1980s, audio conferencing equipment accounted for about 90% and transmission-related costs about 75% of the teleconferencing market. In 1980, video conferencing activity was limited primarily to analog transmissions, with some research with digital techniques. The total video conferencing market, including transmission systems, was about $50 million. As higher-priced video compression equipment and elaborate conferencing centers were introduced in 1982 and 1983, the ratio began to change. By 1984, the teleconferencing market had grown to approximately $245 million, and the video component was $90 million, or more than one-third of the total. Table 7 shows the estimated audio and video markets in 1984 and 1990, as reported by the University of Wisconsin. [Ref. 41:p. 67-89]

Another world-wide teleconferencing trend analysis was conducted by Douglas for the years 1988 to 1991. That author reports: "...although the videoconferencing industry is still in its infancy, it is a market ready to bloom. Costs are going down and performance and availability are going up" [Ref. 42:p. 38]. Digital videoconferencing expenditures in 1988 represented $230 million. This was about 29% of the total global market for all forms of teleconferencing, which was approximately $800 million at the end of 1988 (see Figures 16 and 17). About half of the world's videoconferencing takes place in U.S. European countries represent about 30% of the world market for

interactive videoconferencing, and Japan leads the Far East in using, developing, and investing in the equipment.

TABLE 7. ESTIMATION OF TELECONFERENCING MARKETS
[Ref. 41:p. 89]

Type of conference	Estimated market, Millions of dollars	
	1984	1990
Audio, audio-graphic conferencing:		
Equipment, services, and facilities	45	375
Transmission	110	270
Total audio expenditures	155	645
Video conferencing:		
Equipment, services, and facilities	65	745
Transmission	25	370
Total video expenditures	90	1,115
Total teleconferencing expenditures	245	1,760

Hardware costs are decreasing and the importance of software-based products is increasing. Most North American, Northern European, and Japanese telecommunications managers will have the ISDN by the early 1990s, opening the market for a new generation of videoconferencing products [Ref. 42:p. 39]. Within the next five years, desk-to-desk teleconferencing may spur the growth of videoconferencing, with the camera and codec systems being two of the options available for office workstations.

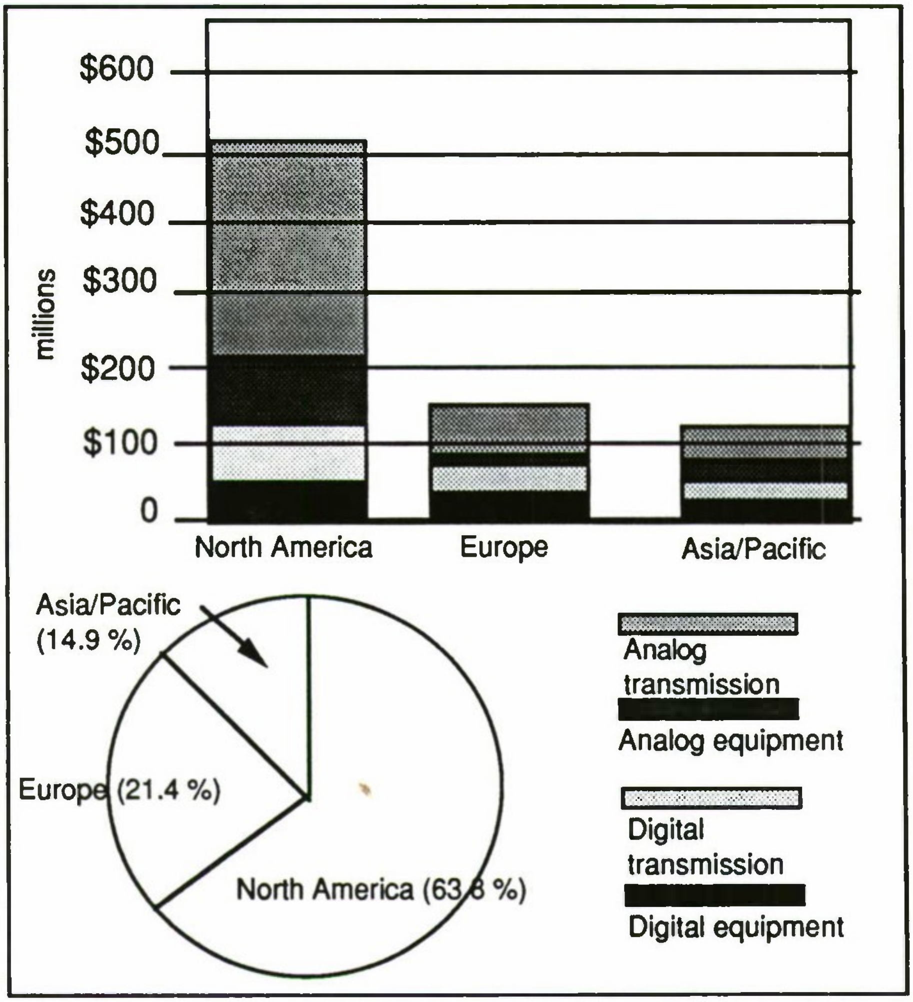

Figure 16. Worldwide 1988 Teleconferencing Revenues for All Types of Systems
[Ref. 42:p. 38]

In July 1990 the CCITT is expected to recommend transmission rates in multiples of 64 kbps as an international standard for videoconferencing systems. The standard will be finalized by 1992. [Ref. 42:p. 40]

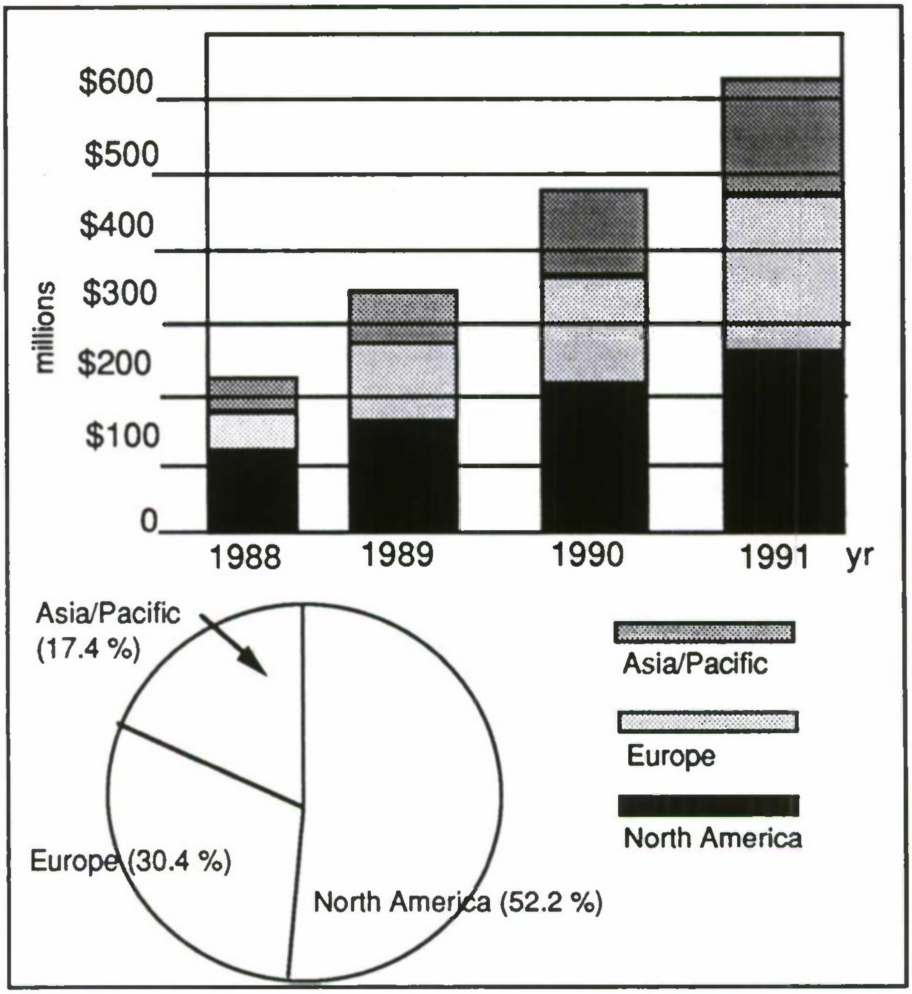

Figure 17. Trend of Worldwide Revenues for Digital Videoconferencing Systems
[Ref. 42:p. 40]

E. SUMMARY

Five categories of teleconferencing technology have been discussed, along with guided and unguided transmission media and the trend of teleconferencing. Based on the information found in study above, suitable transmission media to link a 200-mile domestic videoconferencing system are satellite and fiber optic systems. Considering Taiwan's current environment, the advantages of using fiber optics instead of satellite links are as follows.

- Longer system life cycle: the average life of fiber optic systems is 10 to 15 years, versus 7 to 10 years for satellite systems.
- Lower initial cost: the fee of leasing existing fiber optics cable systems is much lower than the cost of building earth stations for a satellite system.
- Lower maintenance cost: fiber optic systems have fewer connections and components; therefore, the maintenance cost is much cheaper than for complicated satellite systems.
- Lower operational cost: no operator is needed to operate a fiber optics system, but a control center and leased satellite channels are required to operate a satellite system.
- Immunity to electromagnetic interference: fiber optics are dielectric; satellite systems can be effected by certain kinds of electromagnetic interference.
- Higher security: it is much more difficult to tap into fiber optics systems than into satellite systems.
- Higher capacity: fiber optics have almost unlimited wide bandwidth, but satellite systems have limited channels.
- Higher expansion capability: fiber optic cable systems can be expanded to act as a backbone of a wide area network without significant extra cost.
- Higher availability: users can have full access control of fiber optic systems, access to satellite channels is limited by contract.
- Higher reliability: compared to the complex technology of satellite systems, fiber optic systems are more reliable since they have fewer components.
- Greater flexibility: the ability to change modulation techniques is greater when using fiber optics than with satellite systems.
- Shorter implementation time: fiber optic cables already exist for Taiwan domestic use; a time-consuming acquisition process is required to lease satellite channels from a foreign country.
- Less transmission delay: the transmission delay between Taipei and Kaohsuing is 1 ms using a fiber optic system and 240 ms via satellite system.

The disadvantages are as follows.

- Less mobility: fiber optic systems have their routes and links fixed, but satellite systems can change both transmission routes and link locations.
- Problems with domestic dispersion: geographical dispersion of the transmission system, including linking the islands into the system, will cost much more for fiber optic cable installation than satellite systems would cost.
- Lower international link capability: the cost for fiber optic international links is much higher than for satellite system links.
- Lower survivability in natural disasters: natural disasters such as typhoons and earthquakes can cause more damage to fiber optic systems than to satellite systems.
- Fewer opportunities for new jobs: to operate and maintain a fiber optic systems requires fewer people than satellite systems would require.

The ROC will not have satellite-launching capability until December 1993. However, fiber optic systems already are in use for the ISDN, and could also be used for domestic teleconferencing system development [Ref. 43:p. 1]. Therefore, it is technically feasible to use pre-ISDN fiber optic links for a point-to-point, 200-mile domestic videoconferencing system. Such a system would be cost effective and would meet the military conferencing needs of the ROCN.

III. HUMAN FACTORS RELATED TO TELECONFERENCING

Teleconferencing is an intrinsically complex service, and human factors design is an essential ingredient in making the service usable [Ref. 45:p. 164]. This chapter includes an introduction to human factors, as they relate to teleconferencing systems. Considerations related to system users are discussed, an interface design for an ROCN system is proposed, and the effects of human factors on design of teleconferencing systems are summarized.

A. INTRODUCTION OF HUMAN FACTORS

Human factors is the term used in the United States and a few other countries, for the discipline that applies knowledge about human limitations and capabilities to the design of systems, through research and engineering. The term *ergonomics* is more prevalent in Europe and the rest of the world [Ref. 46:p. 4].

1. Definition of Human Factors

Sanders and McCormick provide the following definition: "Human factors discovers and applies information about human behavior, abilities, limitations, and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for productive, safe, comfortable, and effective human use." [Ref. 46:p. 5] Several doctrines characterize the human factors profession. These include the following items.

- Commitment to the idea that things, machines, etc., are built to serve humans and must be designed always with the user in mind.
- Recognition of individual differences in human capabilities and limitations and an appreciation for their design implications.

- Conviction that the design of things, procedures, etc., influences human behavior and well-being.
- Emphasis on empirical data and evaluation in the design process.
- Reliance on the scientific method and the use of objective data to test hypotheses and generate basic data about human behavior.
- Commitment to a systems orientation and a recognition that things, procedures, environments, and people do not exist in isolation. [Ref. 46:p. 5]

As with many professions, misconceptions about the human factors job can limit its usefulness. To refute some of these misconceptions, Sanders and McCormick note the following factor.

- Human factors is not just applying checklists and guidelines.
- Human factors is not using oneself as the model for designing things.
- Human factors is not just common sense. [Ref. 46:p. 6]

2. History of Human Factors

The development of the human factors field has been inextricably intertwined with developments in technology and as such had its beginning in the industrial revolution of the late 1800s and early 1900s. During the early 1900s Frank and Lillian Gilbreth began their study of skilled performance, fatigue, the design of work stations, and equipment for the handicapped. Emphasis was on the study of human motions and on shop management [Ref. 46:p. 6].

At the end of the World War II in 1945, engineering psychology laboratories were established by the U.S. Army Air Corp (later to become the U.S. Air Force) and U.S. Navy. In 1949 the Ergonomics Research Society was formed in Britain, and the first book on human factors was published, entitled *Applied Experimental Psychology: Human Factors in Engineering Design* (Chapanis, Garner, and Morgan, 1949). [Ref. 46:p. 7]

In 1959 the International Ergonomics Association was formed to link several human factors and ergonomics societies in various countries around the world. Until the 1960s, human factors in the U.S. was essentially concentrated in the military-industrial complex. With the race for space and manned space flight, human factors quickly became an important part of the space program. Computer technology has provided new challenges for the human factors profession. New control devices, information presentation via computer screen, and the impact of new technology on people are all areas where the human factors profession has made contributions. [Ref. 46:p. 8]

B. VIDEOCONFERENCING USERS, TASKS, AND ENVIRONMENT FOR THE ROCN

A system's users, the users' tasks, and the system environment must be defined prior to system design, if human factors are to be considered. The following sections describe the anticipated users and their tasks, along with the probable environment of a ROCN videoconferencing system, as a reference for further requirements design .

1. Teleconference System Users

Based on assumptions noted in Chapter II, the main purpose of the ROCN videoconferencing system is for decision making meeting between military personnel located in Taipei and Kaohsuing. Therefore, this chapter assumes that most users of this videoconferencing system are male Chinese Naval officers that are senior in rank (commander and above), and from 35 to 65 years old. The average height of these users is 173 cm (68.3 in). Teleconferencing participants will be concerned about the information that is

communicated. They also will be sensitive to nonverbal cues, which include facial expression, emotion expressed via voice, gestures, and the seated and standing posture of participants.

2. Teleconferencing Tasks

The task of the users of the ROCN videoconferencing system will be to make decisions. Thus the task of this system is to provide a helpful tool to serve the remote group decision-making process. Figure 18 provides a simple model of the man-machine interfaces of a videoconferencing system.

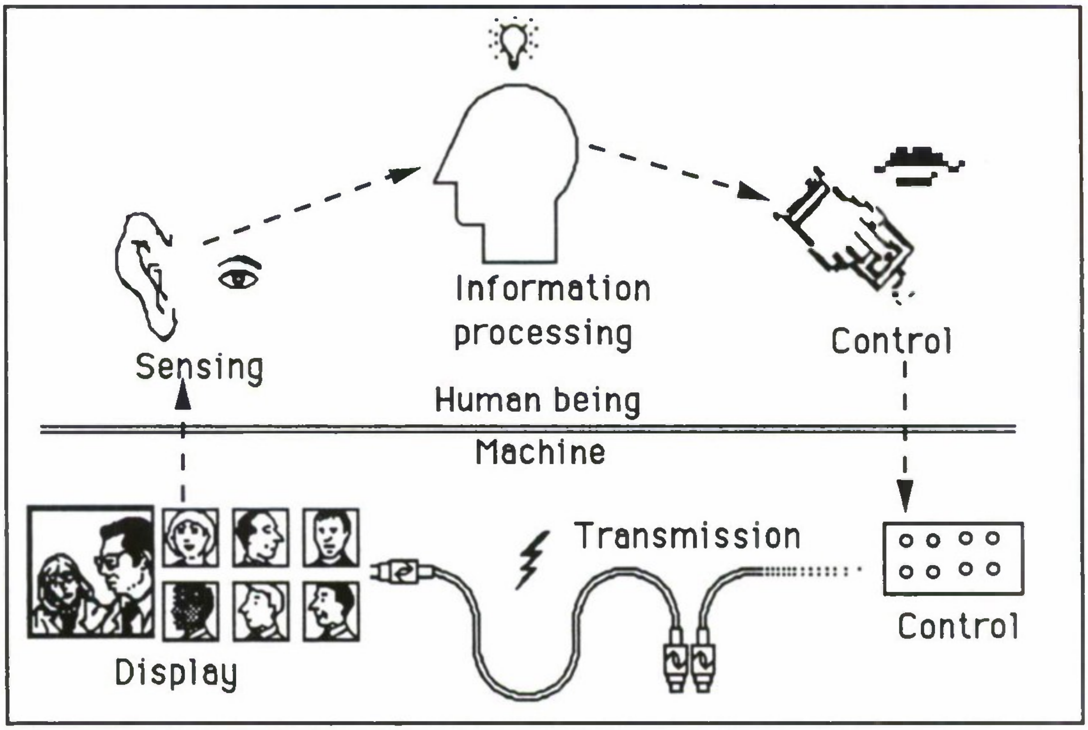

Figure 18. Man-Machine Interfaces
[Ref. 46:p. 14]

As illustrated there, human information processing is central to system operation. Decision making is an integral component of information processing. The decision-making process is shown as a flow chart in Figure 19. It is a complex process by which people generate and evaluate

alternatives, then select a strategy to execute. The process involves seeking information relevant to the decision at hand, estimating probabilities of various outcomes, and attaching values to the anticipated outcomes. [Ref. 46:p. 15]

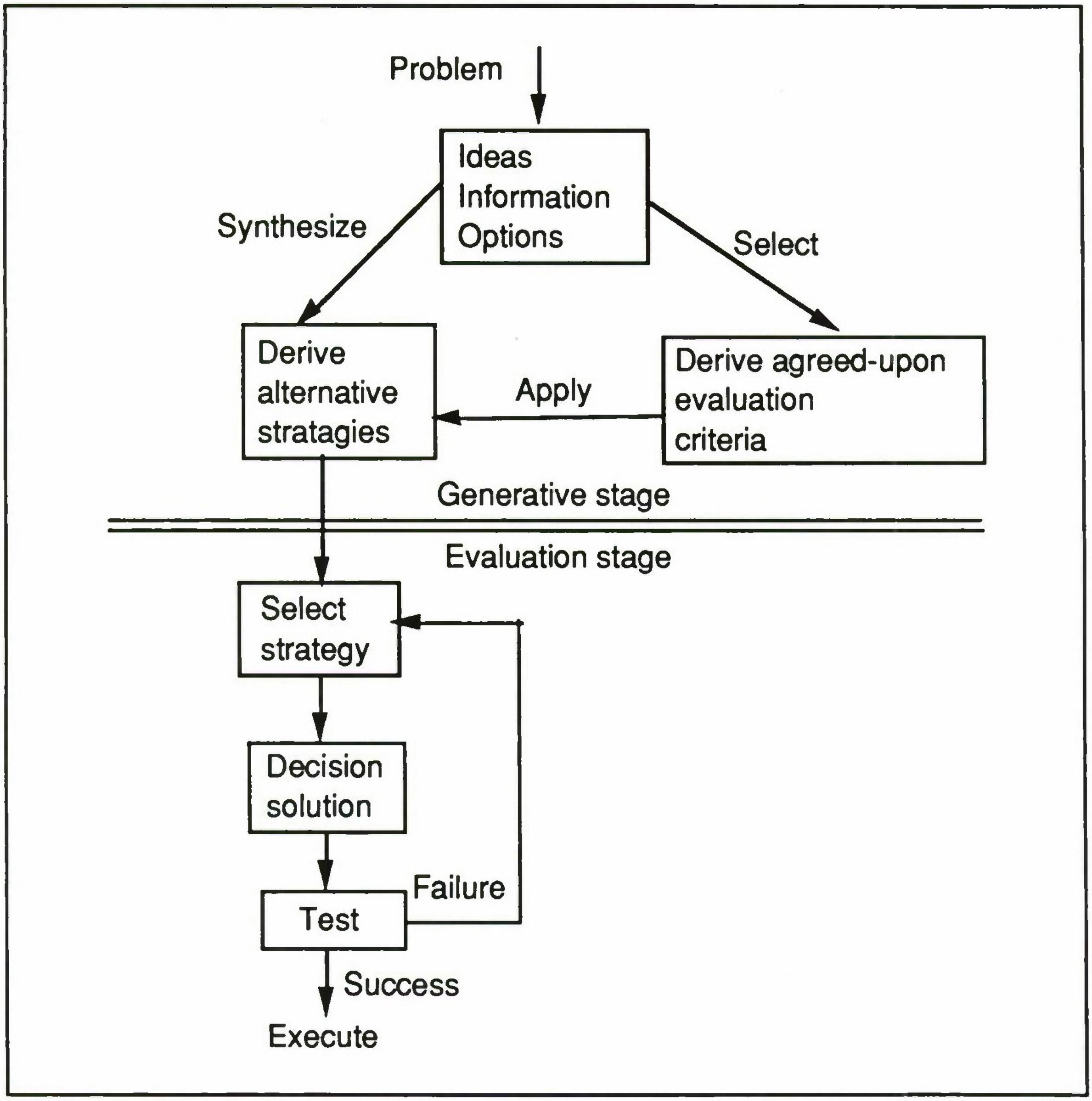

Figure 19. Decision-Making Process
[Ref. 47:p. 439]

In video teleconferencing, both visual and aural information must be processed simultaneously; conferees must pay attention to both of these sensory channels at the same time, using ***divided-attention*** processing [Ref. 46:p. 66]. Sanders and McCormick offer several design guidelines for information input for divided-attention tasks. These guidelines include the following.

- Where possible, the number of potential sources of information should be minimized.
- Where timesharing is likely to stress a person's capacity, the person should be provided with information about the relative priorities of the tasks so that an optimum strategy of dividing attention can be formulated.
- The tasks should be made as dissimilar as possible in terms of demands on processing stages, input and output modalities, and memory codes.
- Especially when manual tasks are timeshared with sensory or memory tasks, the greater the learning of the manual tasks, the less will be their effect on the sensory or memory tasks. [Ref. 46:p. 68]

3. Teleconferencing Environment

The physical environment is another important factor related to videoconferencing system design. The following assumptions are made about the physical environment around which a videoconferencing system in Taiwan must be designed.

- Conferences will be indoors.
- Indoor illumination levels will be: 200-500 lux [Ref. 46:p. 408].
- Area noise level will be between: 40-104 decibels [Ref. 46:p. 459].
- Outside temperature will be: 16°-36.7°C (61°-98°F) for the Taiwanese subtropical climate.
- Relative humidity can be expected to be: 80-95%.
- Air pressure will be: normal atmosphere.
- Natural threats are possible, including typhoons (average 6 per year) and earthquakes.

As a result of these conditions, special consideration must be given to the design of the area in which videoconferencing will take place. Steps must be taken to reduce noise levels and humidity, to moderate the temperature, and to protect conference participants from the effects of natural threats.

C. PROPOSED DESIGN OF ROCN VIDEOCONFERENCING SYSTEM INTERFACES

In a study conducted in 1985, researchers found that, "Probably more than any other factor, the architectural design of the room determines how readily users accept and feel comfortable with a teleconferencing system" [Ref. 48:p. 18]. The needs of the user must be balanced against equipment limitations.

Basically, three types of videoconferencing facilities are available on the current market: fully-installed rooms, self-contained systems (portables), and desk top units [Ref. 49:p. 20]. A fully-installed room is specifically dedicated to videoconferencing. It is constructed or modified based on certain requirements, including acoustical treatment and proper lighting arrangement. Organizations that plan to use videoconferencing as an important strategic tool often choose the dedicated room approach. Including construction and all equipment, a videoconferencing room can cost between $200,000 and $350,000 in the U.S. [Ref. 49:p. 20].

Self-contained systems generally have the same features as a dedicated room. They still require acoustical and lighting treatment, but overall modification costs are less. These facilities are appropriate when a company wants to use videoconferencing without making a construction commitment, since the equipment can be disconnected and moved from room to room. However, if the room is dim and noisy the entire system can be ineffective.

Prices in the U.S. for portable systems can range from $14,000 to more than $200,000. Cost savings result from a lessened need for permanent construction. [Ref. 49:p. 21]

Desktop videoconferencing units include both motion video and still-frame technologies. These systems have fewer and less sophisticated features than the other types of videoconferencing facilities, and therefore cost less. However, it is difficult to isolate these system from noise and other adverse environmental factors because controllers, computers, and other equipment are incorporated into a desktop network. Cost difference of desktop system can vary several thousand dollars in the U.S., it range from $20,000 to $65,000 [Ref. 49:p. 21].

Decision-making meetings of ROCN officers, using videoconferencing, will require an almost face-to-face group meeting atmosphere. Thus, desktop units are unlikely to meet requirements due to fewer features and limited visibility of participants. However, both fully-installed rooms and portables may meet the requirements. Both of these types of facilities require proper room design for effective equipment use. Visual, acoustic, space, temperature, humidity, and security elements all must be considered by the design engineer as he develops a videoconferencing room to meet the ROCN users' needs and system requirements.

1. Visual Requirements for Videoconferencing Rooms

Visual display is a very important factor for videoconferencing. This factor includes room illumination, use of color, and display of images. For satisfactory human performance, visual display requirements includes the following.

- Room illumination level should range from 300 to 500 lux, with color temperature approximating normal day light (in candescent and warm white florescent) [Ref. 46:p. 419 and Ref. 51:p. 559].
- The color of the room should be in the blue-green range, according to the "hue-heat hypothesis" that colors in this range produce feelings of coolness [Ref. 51:p. 555]. Colors should not be distracting to the participants.
- All surface in the room should be designed to prevent glare.
- The cameras should be mounted so conferees can look directly into the video monitors to have "virtual eye-contact" with their counterparts.
- Images of conferees on the video monitors should be as close to real size and height as possible.
- The color of all images on the monitors should be as natural as possible, and luminance levels and resolution should be adequate for comfortable viewing and rapid image identification by conferees.
- All graphics and text on the monitors should be easily readable and understandable by the normally-seated conferees, without visual straining.
- All printed materials should be easily readable and understandable by the intended readers.

2. Acoustics Requirements for Videoconferencing Rooms

Videoconferencing rooms must meet several criteria related to acoustical considerations. These speaker fidelity, microphone howling control, noise isolation, and echo absorption [Ref. 50:p. 50]. Adequate human hearing of sounds related to videoconferencing requires that the following room design factors be considered.

- Ambient noise level should be approximately 40-60 dB, by sound-proofing or room isolation if necessary [Ref. 54:p. 553].
- Echoes and extraneous noise should be minimized by using acoustic absorbing materials on walls surfaces [Ref. 53:p. 80].
- Microphones and the speakers should be placed in the room so that howling is prevented [Ref. 53:p. 79].
- Speakers and microphones should be mounted properly so they do not distract the conferees' attention away from the video monitors.

- The power and fidelity of speakers should be adequate for minimal audio distortion.
- Sounds should be approximately as loud, clear, and natural as they would be during face to face conversing.

3. Space and Equipment Arrangements for Videoconferencing Rooms

During teleconferencing sessions, the dispersion of conferees among various locations sometimes can improve decision accuracy for some tasks. However, it has been shown that interpersonal conflicts tend to be greater, communication becomes less efficient, and satisfaction with the group process tends to decline [Ref. 55:p. 598]. Group verbal productivity may increase as conference groups increase in size; this may not be directly attributable to the addition of other speakers but rather to the addition of other listeners [Ref. 56:p. 41]. Huber indicates "...group size and the proximity of members during the meeting appear to be the most critical factors to group decision support systems design" [Ref. 57:p. 198]. The importance of these factors true to videoconferencing room design also cannot be overlooked.

For an effective group decision-making meeting, DeSanctis and Gallupe suggest five people in the group, Franklin recommends seven members, and a Johns Hopkins University study indicates that four people is most effective [Ref. 58:p. ME-1]. Based on this information, it is proposed that the ROCN use a video conferencing room that is adequate for group number range from four to seven people. Video conferencing will connect more than one room for a meeting and meeting participants may be required to vote as they make decision. Thus the total number of conferees probably should be an odd number to ensure that ties do not result [Ref. 59:p. 197]. Figure 20 shows a basic arrangement for video conferencing rooms that could

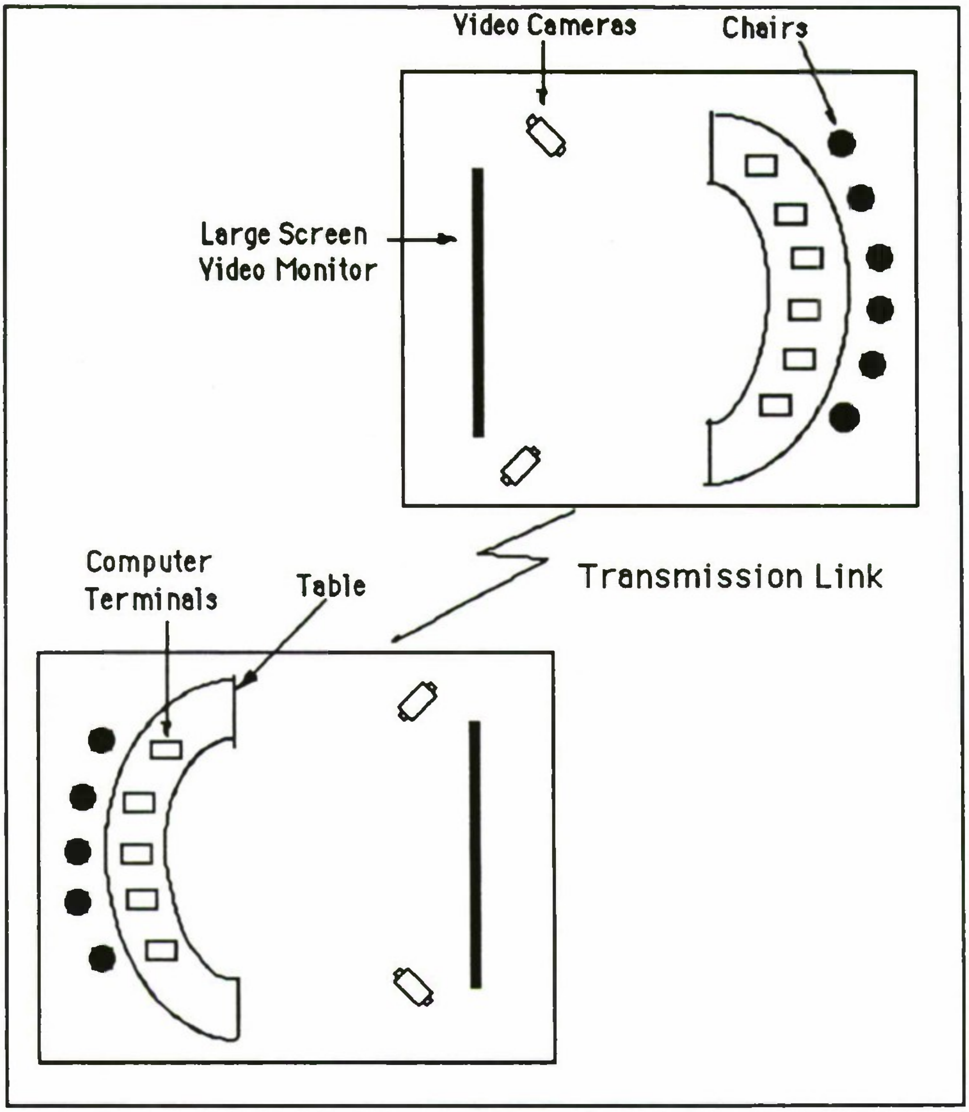

Figure 20. Basic Arrangement of Video Conferencing Rooms
[Ref. 59:p. 195].

be used for ROCN decision-making meetings. Each room has the same equipments and can "see" the other room through the large screen video monitor. Video cameras are rotatable mounted and automatic focus on the speaker while the speaker is speaking, the position of each speaker should be coded and triggered by control key. Thus, whenever the control key on the control panel was been pushed the camera will identify the person and

display his image on the large screen. The display of the whole group can be controlled by facilitator or by conferees themselves, no additional operators or control rooms are needed.

Conferee workspaces can be a critical issue in video conferencing room design. The U.S. Public Health Service conducted a survey in 1965, using a representative sample of 6672 adult males and females with heights ranging from 150 to 190 cm (59 to 72.8 in) [Ref. 46:p. 332-333]. Since the users of ROCN videoconferencing system will be male officers with an average height of 173 cm (68.3 in), data from that survey maybe useful in the design of workspaces for videoconferencing conferees.

The workspace for each individual conferees should includes a work table and chair; a control panel, and possibly a computer terminal should be provided for the facilitator.. The requirements for these items are as follows.

- Table height: the table height should range from 69 to 78 cm (27 to 31 in) to accommodate seated personnel comfortably [Ref. 46:p. 344].
- Table surface: a non-glare table surface that is slanted 12 degrees toward the conferee should be used, for minimizing eye fatigue and discomfort [Ref. 46:p. 343].
- Table shape: a horseshoe-shape is the most commonly used one; conferees then can see their distant counterparts on the large screen video monitor and feel as if they are in the same room [Ref. 55:p. 599].
- Chairs spacing: chairs should not be fixed to the floor or attached to the table, to allow the conferees to adjust their closeness to the table and to each other.
- Chair back: seat backs should provide support for the lumbar area and should have moderate angle (10 to 30 degrees from vertical) [Ref. 46:p. 354].
- Chair pan: seat pans should slope back slightly and the angle between seat pan and back should be between 95 and 120 degrees [Ref. 46:p. 355].
- Chair height and width: seat height should be low enough to accommodate for small people (36 cm or 15 in) and adjustable; the seat

width should be adequate for large people (46 cm or 18 in) [Ref. 46:p. 355].

- Facilitator's control key pad: the key pad for controlling the audio and video systems should be mounted in front of the facilitator who controls the agenda and meeting progress. Minimum pushbutton diameter should be between 13 mm (5 m-in), with 5 mm (1.95 m-in) displacement. Pushbutton resistance should be 280 to 1130 grams (10 to 40 ounces), and control should be separated by about 13 mm (5 m-in) [Ref. 51:p. 320].
- Control pad labels: all control keys should be clearly labeled, and with the labels readable and understandable.
- Computer terminal: if one is present, the computer terminal should serve as a resource for data needed during the meeting; it should be portable and be mounted so it does not block the conferees' view. The computer's controls and display formats should be easy to use and to understand, recognizing that the users may not routinely use this particular system.
- Microphone and cameras: this equipment should be mounted do it is hidden, if at all possible, minimizing the nervousness of conferees.

4. Temperature and Humidity Considerations

Its subtropical island climate makes the weather in Taiwan warm and humid. These conditions result in fatigue and discomfort during indoors conferences. Therefore, temperature and humidity must be taken into account while designing a videoconferencing room for the ROCN. For maximum conferee comfort and performance, the temperature of a videoconferencing room should be maintained between 24° and 28°C (75° and 82°F) [Ref. 46:p. 437]. A dehumidification system will be needed to decrease air humidity to between 60% and 30%, to increase conference participants' efficiency [Ref. 60:p. 336]. The noise generated by both air conditioning and dehumidifying systems should be minimized to the greatest possible extent.

5. Videoconferencing Room Security

Videoconferencing room security is as important as is workspace design. Military decision-making meetings require a certain level of secrecy. This is a major reason that it is proposed that the ROCN use fiber optics as the transmission medium for its domestic videoconferencing system. For security, the following steps should be taken.

- A hardened and shielded building on a military base should be used to house each video conferencing room.
- The video conference room should be securely locked when not in use.
- Magnetic detectors or equivalent systems should be used to ensure that illicit listening devices have not been brought in or hidden in the room.
- Security checks should be made prior to and after each conference.
- Personnel access to the building and to the conference rooms should be strictly controlled.
- Prevision should be made for the storage, handling, and use of classified documents needed for videoconferences.

D. HUMAN FACTORS EFFECTS ON TELECONFERENCING

The effects of good human factors design on teleconferencing are difficult to categorize and to quantify since these design factors are interrelated and implementation results cannot easily be separated out. However, some major effects on the system design and the decision-making task can be identified as follows.

- System integration: human factors design will make the teleconferencing system more compact while keeping it fully useable by all participants. As a result, system integration will be easier as only a minimum amount of space will be required.
- System cost: including human factors in the design process will increase the cost of a teleconferencing system, although this increase will be minimized if these factors are considered from the onset of the design process. On the other hand, the overall feasibility of system

implementation may be increased, reducing total lifetime costs of the system. Anticipated cost of a system as described in this chapter is about $125,000 to $200,000 [Ref. 61].

- Decision effectiveness: interfaces designed with human factors in mind will reduce extraneous noise and filter out unnecessary massages and information. Important information then will not be confounded with distracting influences, increasing the effectiveness of decision making.
- Efficiency: conferences can be carried out more efficiently when a well-design user interface minimizes errors in handling system controls; the efficiency of decision making can be increasing by minimizing distractions that slow down mental processing. Information exchange will be concentrated, which is helpful for rapid decision making.
- Fatigue reduction: proper illumination, image and text display, and speaker fidelity should decrease participant fatigue and increase the ability of participants to make effective decisions over a longer period, should extended meetings be necessary.
- User satisfaction: inclusion of human factors in the design should increase the comfort of participants through use of non-distracting colors for the room, isolation of the conferees from outside noises, mounting of cameras and microphones to minimize participants' nervousness and tension, provision of adjustable chairs to accommodate people of various sizes, design of the facilitator's controls to ensure that these can be used correctly and rapidly, and temperature and humidity control to maximize efficiency. However, the fact that conferees use microphones and appears on camera may increase nervousness and tension.

E. SUMMARY

A well-designed teleconferencing system should consider human factors as a key element during the design phase. This can be expected to minimize the chances of user rejection and facilitate the implementation of the new system. Considering the anticipated users, their tasks, and the environment, this chapter has included some basic human factors requirements for ROCN decision-making videoconferencing room design. According to an estimate of Fluor Daniel Corporation, the basic cost of one teleconferencing room

which includes most of the requirements noted in this chapter will range from $125,000 to $200,000 in the U.S. market [Ref. 61].

IV. ECONOMIC EVALUATION

A. INTRODUCTION

Economic analysis is a systematic investigation of the relationships between competing alternatives, in an effort to choose the most economical one, given budget limitations. The technique is based on the premise that there are alternative ways of reaching an objective and each alternative requires certain resources and produces certain results. An economic analysis examines and relates the costs, benefits, and uncertainties of each alternative in order to determine the most cost-effective means of meeting the objective. In a sense, this analysis leads to a more efficient use of resources.

An economic alternative is that alternative which can meet the following criteria.

- Maximizes effectiveness when costs are equal.
- Minimizes cost when effectiveness is equal.
- Provides maximum effectiveness-to-cost ratio when costs and effectiveness are unequal. [Ref. 62:p. 1]

Three basic principles must be incorporated in an economic analysis.

- The analysis must investigate all reasonable alternative methods of satisfying a given objective. To be reasonable, an alternative must be both technologically and operationally feasible.
- The analysis must consider both current and future expenditure patterns for all proposals.
- The analysis must consider not only how much a proposal will cost, but also when the expenditures will be made. This consideration is included in the analysis by expressing each alternative's life-cycle costs in terms of its "present value." [Ref. 63:p. 1-2]

Economic analysis is subject to the following limitations.

- Economic analysis dose not normally establish priorities among various goals and objectives--it merely seeks to determine the most cost-effective means of satisfying a given objective.
- It is not a substitute for sound judgement; it is only an input as one of the factors to the decision-making process.
- An economic analysis cannot provide results which are more valid than the input data.
- No matter how much care is exercised during the decision-making process, uncertainty cannot be eliminated completely.
- A complete economic analysis of even a fairly limited problem can become very involved and expensive. [Ref. 63:p. 1-4]

B. ECONOMIC ANALYSIS METHODOLOGY

The economic analysis process is a systematic procedure for comparing alternative means of meeting a specific objective. The methodology in this study consists of seven major steps, depicted diagrammatically in Figure 21. They are as follows.

1. Initiate the process by determining that there is a need for the system and identifying alternative systems that will meet that need.
2. Formulating appropriate assumptions, which includes defining the goal and constraints.
3. Select one suitable alternative system for meeting the need and accomplishing the goal.
4. Estimate the system life-cycle tangible costs and benefits of the selected alternative.
5. Compare the tangible life-cycle costs and benefits for the selected alternative. If costs are less than benefits, then install the selected system; otherwise,
6. Determine the criticality of the system. If the need is not critical to the organization, then save the collected data for future reference and stop the analysis; otherwise,

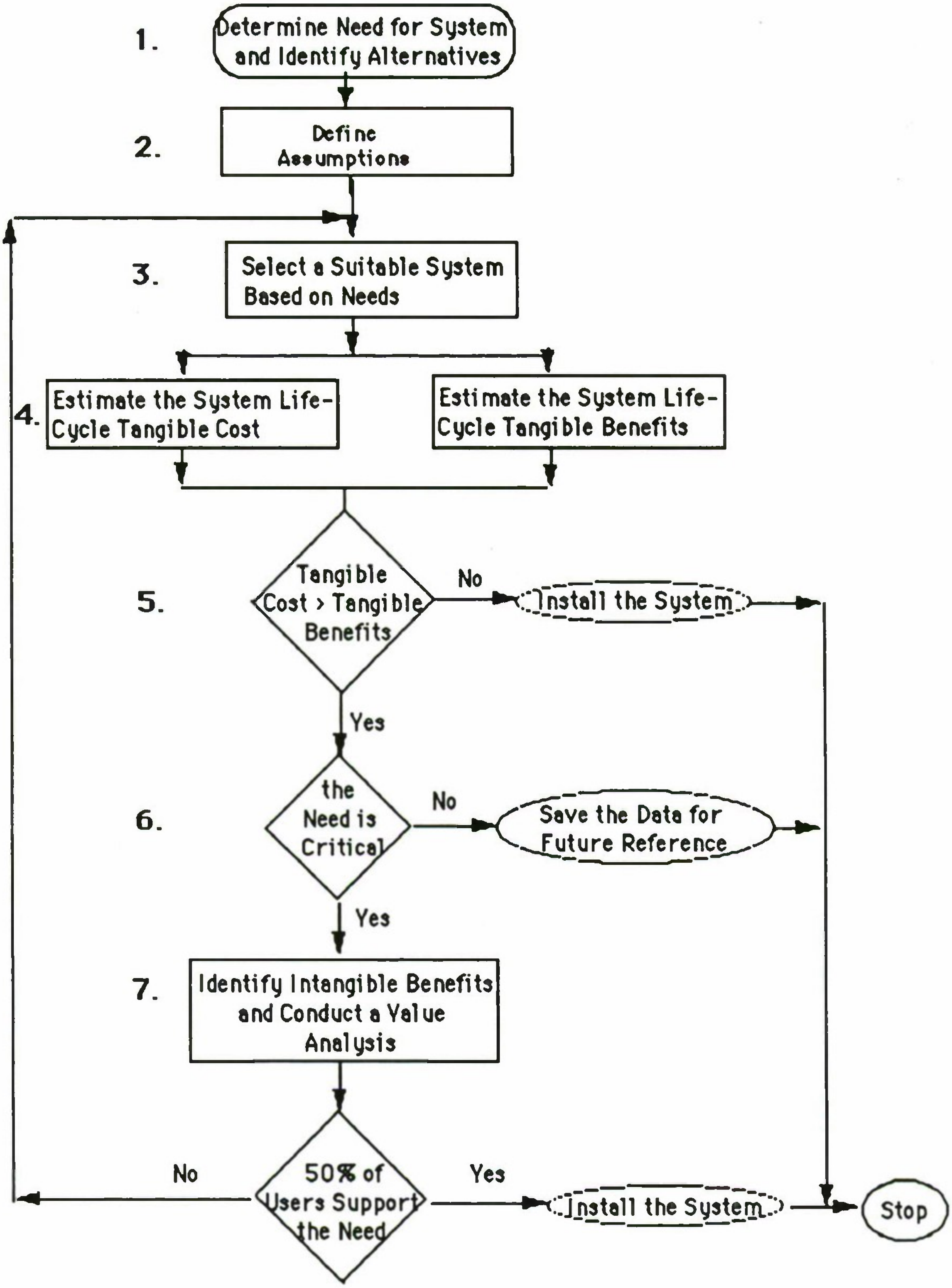

Figure 21. Economic Analysis Methodology

7. Determine intangible benefits of the system to potential users by using a well designed questionnaire to collect data; use these data to conduct a value analysis. If 50% or more of users support the need, then install the system even if it is costly; otherwise, return to step 3 and select another alternative for analysis.

The ROCN's need for teleconferencing systems has been discussed in Chapter I. The following sections describe the economic analysis process in detail from step 2 to step 7.

C. ASSUMPTIONS

Not all cost data related to selection of a teleconferencing system are available from industry and the ROCN. Thus, the economic analysis must start with certain appropriate assumptions. These assumptions include the following.

- The objective of this analysis is to determine at least one feasible and economic teleconferencing system for the ROCN and the operation scale at which it will be economical.
- A system related to ROCN's national defense, operational safety, security, or operational effectiveness is considered critical.
- The first phase of the teleconferencing system will link directly from Taipei to Kaohsuing, for room-to-room decision-making meeting use only.
- The system will have a 10-year life cycle.
- The ROCN will import videoconferencing equipment, install it in rooms at one or more Naval bases, and lease the fiber optics cable from the Directorate General of Telecommunications (DGT).
- The Taiwan DGT will provide the fiber optics cable for domestic ROCN videoconferencing system linkage, and charge its uniform leasing fee of NT$ 9,000 ($350) per hour of line use throughout the system's life cycle [Ref. 64:p. 6].
- On the average, 60 meetings per year (five meetings per month) will be conducted using the videoconferencing system. Each meeting will last an average of 2 hours, resulting in 120 hours per year of system usage.

- On the average, 10 conferees at every meeting would need to travel between Taipei and Kaohsuing, if there were no videoconference capability, and it costs the ROCN NT$ 1,000 ($40) per trip per man for transportation. Additionally, food and lodging for each trip will cost NT$ 500 ($20) per day per man.
- The average labor cost of ROCN senior officers is NT$ 175 ($7) per hour per man. For each face-to-face meeting requiring travel, there are eight hours of productivity loss.
- Except for the number of meetings, all other factors considered in this analysis should remain constant.

D. SELECT A SUITABLE SYSTEM BASED ON NEEDS

Chapters II and III have described procedures which can be used for selection of a teleconferencing system for decision-making meetings. These procedures should be reviewed and considered by the ROCN in making such a selection among the alternatives that are available.

E. COST OF SELECTED TELECONFERENCING SYSTEM

Obtaining any kind of system includes tangible costs and intangible costs. This section estimates the tangible life-cycle cost for one selected videoconferencing system, based on information provided in Chapter III and the assumptions above. The intangible costs of the selected videoconferencing system are very difficult to be quantify before its implementation. However, some possible intangible costs are identified.

1. Tangible Costs Related to an ROCN Videoconferencing System

For purposes of economic analysis, tangible costs are separated into two categories: non-recurring and recurring. Non-recurring costs occur on an one-time basis; they are typically associated with the start-up or implementation of an alternative. Recurring costs occur on a repetitive, year-to-year basis; they are needed to sustain an alternative throughout its life-

cycle, once it has been implemented. Costs which have already been incurred at the time the analysis is made are considered "sunk costs" and are not included in the comparison of alternatives. [Ref. 65:p. 3-2]

There are three essential cost elements in the selected videoconferencing system: equipment, conference room, and telecommunications. A set of full-feature videoconferencing system equipment which can meet all the requirements of Chapter III will cost about NT$ 1,250,000 ($50,000) on the world market [Ref. 66:p. 44]. The design and outfitting of a video conferencing room will cost about NT$ 1,500,000 ($60,000) in Taiwan. This assumes that the building already exists and so is sunk cost. The telecommunications service provided by the DGT will cost NT$ 9,000 ($350) per hour, as a uniform rate throughout the system life cycle [Ref. 64:p. 6]. About NT$ 10,000 ($400) per year of maintenance expenses will be incurred [Ref. 67:p. 42]. Table 8 shows a summary of the videoconferencing system tangible costs during its 10-year life cycle, based on the 60 meetings per year assumption. It may be seen that the cost is expected to be approximately NT$ 16,400,000 ($656,000).

2. Intangible Costs: Time, Opportunities, and Training

Although intangible costs of an ROCN videoconferencing system cannot be calculated, it is useful to identify some of these costs.

- Time spent in system research and development.
- The opportunity cost of selecting one specific teleconferencing system instead of another or no system at all.
- The opportunity cost of tieing up conference rooms for videoconferences.
- Reduction of opportunities for users to travel.

- Education cost to ensure that users know how to use the system and are more willing to do so.
- Training time to teach system operators to use the videoconferencing system.
- Expenditures on the system after completion of its 10-year life cycle.

TABLE 8. VIDEOCONFERENCING TANGIBLE LIFE-CYCLE COSTS, 60 MEETINGS PER YEAR

Cost Elements	Unit Cost (NT$)	Total 10-Year Cost(NT$)
Two Sets of Equipment		2,500,000
Room Outfitting (Two Rooms)		3,000,000
Maintenance		
Maintenance/Year	10,000	
Maintenance/Life-cycle		100,000
Telecommunications		
Lease Cost @ 9,000/Hour		
2 Hours/Meeting		
60 Meetings/Year		
120 Meeting Hours/Year		
Total Lease/Year	1,080,000	
Total Lease/Life-cycle		10,800,000
Total System Tangible Cost for 10-Year Life cycle		**NT$ 16,400,000**

F. BENEFITS OF A TELECONFERENCING SYSTEM

The potential tangible benefits and savings that accrue from a videoconferencing system can be quantized to a certain extent, and productivity enhancements can be identified. However, the following analysis is not a rigorous application of formal cost/benefit analysis techniques, but rather a quick estimate of benefits and savings.

1. Tangible Savings Related to An ROCN Videoconferencing System

The principal savings related to videoconferencing capability will be reduction of travel expenses. The expected ROCN travel costs related to decision-making meeting can be projected based on several assumptions related to average costs. Table 9 shows the videoconferencing tangible benefits and costs during its 10-year life cycle, based on 60 meetings per year.

TABLE 9. VIDEOCONFERENCING TANGIBLE LIFE-CYCLE SAVINGS, 60 MEETINGS PER YEAR

Benefits and Savings Elements	Unit Cost (NT$)	Total Cost (NT$)
Travel Cost Avoidance		
Transportation: Trip/Man	1,000	
Food, Lodging: Trip/Day/Man	500	
2 Days/Trip		
10 Men/Trip		
60 Trips/Year		
Total Costs Avoided/Year	1,200,000	
Total Costs Avoided/Life cycle		NT$12,000,000
Productivity Time Loss Avoidance		
Labor Cost @ 175/Hour/Man		
8 Loss Hours/Trip/Man		
10 Men/Trip		
60 Trips/Year		
Total Productivity Loss Avoided/Year	840,000	
Total Productivity Loss Avoided/Life cycle		NT$ 8,400,000
Total Tangible Savings for 10-Year Life cycle		**NT$ 20,400,000**

2. Intangible Benefits: Productivity Enhancement

Productivity enhancement is an intangible benefit and is more difficult to measure than tangible savings. The most significant areas in which productivity may be enhanced are management and administration.

Productivity should be enhanced in part through improved communication between geographically-separated personnel, using the new videoconferencing capability. Communications on a face-to-face basis allow for instantaneous verbal and visual feedback, and so are more efficient and result in better decision-making and management. A recent study indicates that conferees have better information exchange in a well-designed videoconferencing environment than during face-to-face communication. [Ref. 68:p. 91]

Although productivity enhancement is difficult to quantify precisely before system implementation, it could be estimated from data obtained using questionnaires, yielding an approximate figure in terms of labor reduction. The number of potential users, productive hours per user, percentage by which users benefit, percentage of increased productivity (man-hours), labor cost, etc., are some factors that may be used to estimate the level of productivity enhancement. [Ref. 69:p. 93]

G. COMPARISON OF TANGIBLE COSTS AND BENEFITS

1. Analysis Based on 60 Meetings Per Year

Information provided in Tables 8 and 9 was used to compare overall costs and benefits of implementating a videoconference system for the ROCN. For 60 meetings per year, costs will be NT$ 6,590,000 ($363,600) for the first year; savings for that year will be NT$ 2,040,000 ($81,600). Thus, costs will exceed savings by NT$ 4,550,000 ($182,000) in the first year of implementing the selected system. However, from the second year on, the ROCN will save NT$ 950,000 ($38,000) per year for nine years.

Figure 22 shows a comparison tangible costs and savings for the selected system during its 10-year life cycle expectancy. In total, the ROCN will save NT$ 4,000,000 ($160,000) by using the selected system for ten years, if 60 meetings are held each year.

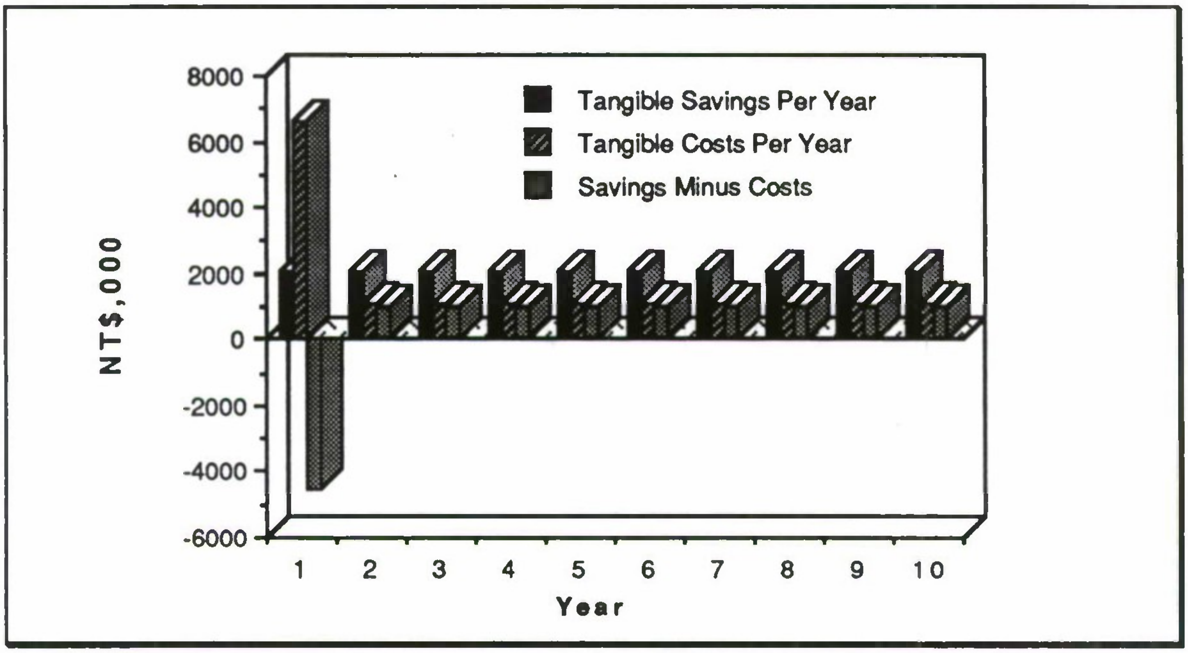

Figure 22. Comparison of Costs and Benefits Associated with Videoconferencing During a 10-Year System Life Cycle, with 60 Meetings per Year.

2. Determination of the Break-Even Point

It is useful to determine the tangible costs and benefits break-even point for use of a videoconferencing system, that is, the point at which the total tangible costs are equal to total tangible savings or the difference is a least non-negative number. If the system can be implemented and operated above this point, it is cost effective for the ROCN to install it. Otherwise, an additional value analysis should be conducted to determine the criticality of the system for ROCN defense.

Further examination of Table 8 shows that some 10-year average costs per meeting (equipment, room, and maintenance costs) are constant, regardless of the number of meetings per year. However, the cost of leasing the telecommunication lines (NT$ 18,000 per meeting) will vary directly with the number of meetings per year. Simple calculations show that the total constant and variable costs per meeting could range from NT$ 578,000 (if only one meeting is held per year) down to NT$ 27,000 per meeting (with 60 meetings per year).

From Table 9 it may be seen that average savings per meeting are independent of the number of meetings held per year. Under the cost assumptions shown in that table, travel costs of NT$ 20,000 and productivity-loss costs of NT$ 14,000 will be avoided for each videoconferencing meeting, for a total savings of NT$ 34,000 ($1,360) per meeting.

As shown in Table 10, costs per meeting and savings per meeting may be combined to yield a savings-minus-costs figure that ranges from -NT$ 544,000 (one meeting per year) to NT$ 6,667 (60 meetings per year) and even higher with more meetings per year. The resulting figures may be multiplied by the number of meetings held each year, to yield a 10-year-average savings-minus-costs value as a function of the number of meetings each year. For one meeting per year, there will be an average loss of NT$ 544,000 ($21,760) per year. For 60 meetings per year, the average savings totals NT$ 400,000 ($16,000) per year, or NT$ 4,000,000 ($160,000) in 10 years. A simple linear relationship may be observed: for each additional meeting held per year, a savings of NT$ 160,000 ($6,400) will be realized during the 10-year system life cycle.

TABLE 10. COMPARISON OF 10-YEAR AVERAGE SAVINGS AND COSTS FOR DIFFERENT NUMBERS OF MEETINGS PER YEAR

	Meetings Per Year							
	1	2	10	20	25	35	50	60
Savings/Meeting, NT$	34,000	34,000	34,000	34,000	34,000	34,000	34,000	34,000
Costs/Meeting, NT$	578,000	298,000	74,000	46,000	40,000	34,000	29,200	27,333
10-Year Average Savings Minus Costs Per Meeting, NT$	-544,000	-264,000	-40,000	-12,000	-6,400	0	4,800	6,667
Meeting Per Year	X 1	X 2	X 10	X 20	X 25	X 35	X 50	X 60
10-Year Average Savings Minus Costs, for Total Meetings in 1-Year, NT$	-544,000	-528,000	-400,000	-240,000	-160,000	0	240,000	400,000

Using this procedure, it may be observed in Table 10 and Figure 23 that 35 meetings per year will result in system costs equaling savings (NT$ 34,000 per meeting). If fewer meetings are held per year, a loss will be incurred; if more meetings are held, a gain will be realized. Table 11 provides a detailed analysis of 10-year tangible costs and benefits when 35 meetings per year are held using the videoconferencing system.

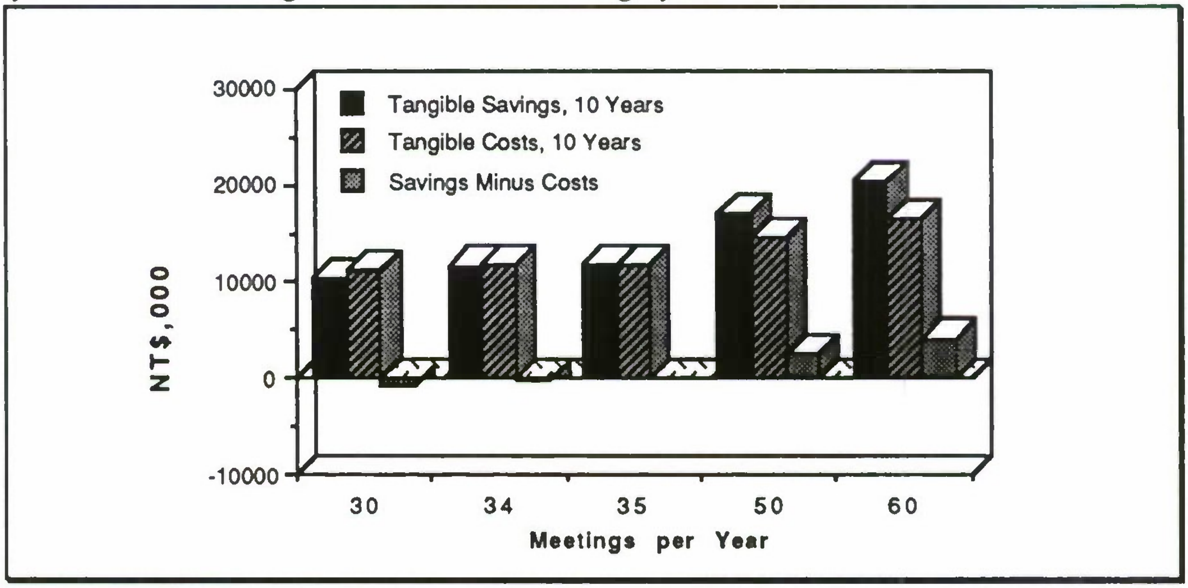

Figure 23. Comparison of 10-Year Costs and Benefits as a Function for Different Numbers of Meetings per Year

TABLE 11. VIDEOCONFERENCING TANGIBLE LIFE-CYCLE COSTS AND SAVINGS, 35 MEETINGS PER YEAR

Cost Elements	Unit Cost (NT$)	Total Cost (NT$)
Two Sets of Equipment		2,500,000
Room Outfitting (Two Rooms)		3,000,000
Maintenance		
Maintenance/Year	10,000	
Maintenance/Life-cycle		100,000
Telecommunications		
Lease Cost @ 9,000/Hour		
2 Hours/Meeting		
35 Meetings/ Year		
70 Meeting Hours/Year		
Total Lease/Year	630,000	
Total Lease/ Life-cycle		6,300,000
Total Tangible Cost for 10-Year Life cycle		**NT$ 11,900,000**
Benefits and Savings Elements		
Travel Cost Avoidance		
Transportation: Trip/Man	1,000	
Food, Lodging: Trip/Day/Man	500	
2 Days/Trip		
10 Men/Trip		
35 Trips/Year		
Total Costs Avoided/Year	700,000	
Total Costs Avoided/Life cycle		7,000,000
Productivity Time Loss Avoidance		
Labor Cost @ 175/Hour/Man		
8 Loss Hours/Trip/Man		
10 Men/Trip		
35 Trips/Year		
Total Productivity Loss Avoided/Year	490,000	
Total Productivity Loss Avoided/Life cycle		4,900,000
Total Tangible Savings per 10-Year Life cycle		**NT$ 11,900,000**

As shown in Figure 24, for 35 meetings per year, costs will exceed savings by NT$ 4,950,000 ($198,000) during the first year of system implementation. However, from the second year on, the ROCN will save NT$ 550,000 ($22,000) per year for nine years. In 10 years of videoconferencing, the savings will exactly equal costs.

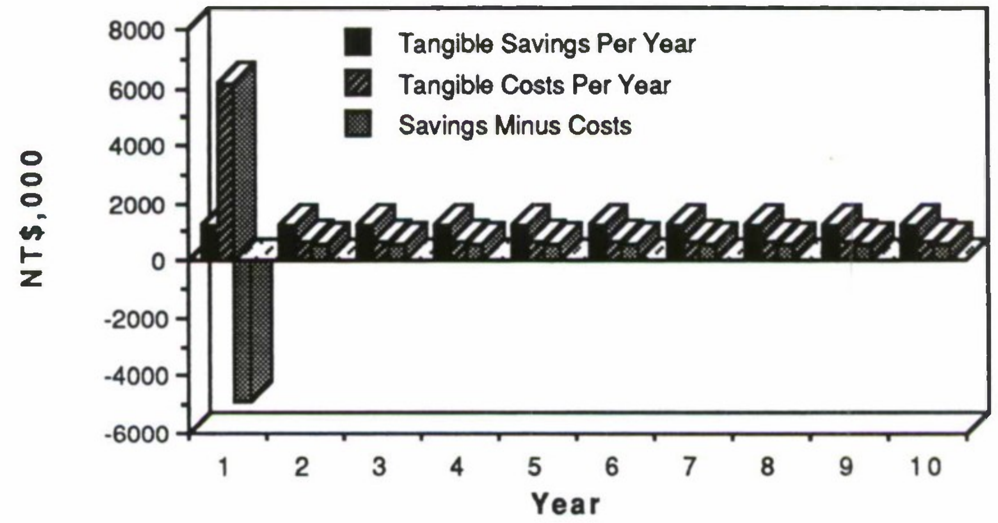

Figure 24. Comparison of Costs and Benefits Associated with Videoconferencing During a 10-Year System Life Cycle, with 35 Meetings per Year.

Based on this comparison, installation of a videoconferencing system that will be used more than 35 times per year will be cost effective. In this case, a need justification and value analysis (steps 6 and 7 on Figure 21) are not required.

H. IDENTIFICATION THE CRITICALITY OF SYSTEM NEEDS

If the new teleconferencing system will be used fewer than 35 times per year, it is necessary to determine whether the need for the system is critical. This is done in step 6 of the economic analysis process in Figure 21. With the

full-feature functions described in Chapter II, the selected ROCN videoconferencing system will facilitate the decision making process and increase the nation's security. These factors relate to national defense and the operational effectiveness of the ROCN, as noted in the assumptions discussed earlier. Thus the need for an ROCN videoconferencing system can be considered critical, even if benefits do not exceed costs. Further analysis is appropriate; that is, a value analysis should be conducted.

I. INTANGIBLE BENEFITS IDENTIFICATION AND VALUE ANALYSIS

Based on the economic analysis methodology shown in Figure 21, when the life-cycle cost of a proposed system is greater than its total benefits, it is necessary to justify the need for the system prior to making a decision. Data on the system's importance may be obtained from potential users through the use of a well-designed questionnaire. An example of such a questionnaire is shown in Table 12, as it might be used to obtain data for a ROCN videoconferencing system value analysis.

Questionnaire results can be analyzed using standard statistical techniques [Ref. 70:p. 27]. It may be assumed that, if more than 50% of potential users support the need, serious consideration should be given to installing the proposed system, even if it is costly. Otherwise, the researcher should return to step 3 on Figure 21 and begin the process again using another alternative which may meet the ROCN's requirements and budget.

TABLE 12. EXAMPLE QUESTIONNAIRE FOR DETERMINING INTANGIBLE BENEFITS OF VIDEOCONFERENCING

Name: ______________________ Title: ______________________

Command: ______________________ Location: ______________________

Interviewer: ______________________ Date: ______________________

- *Please circle one answer for each question, based on your personal experiece.*

1. On the average, how many times per month do you travel to attend official government meetings?

   < 1 1-4 5-10 11-15 16-20 21-30 > 30

2. On the average, how many days do you spend on each trip?

   < 1 1-2 3-5 6-10 >10

3. On the average, how many people attend each of these meetings?

   < 3 4-6 7-10 11-15 16-20 >20

4. What is the average duration of each day's meeting, in hours?

   < 1 1-2 3-5 6-8 >8

5. What is the average time interval in days between the decision that a meeting is required and the date the meeting begins?

   < 1 1-2 3-5 6-10 >10

6. How many times per month do you have conflicting meetings; that is, two meetings are held at the same time in different locations?

   < 1 1-4 5-10 11-15 16-20 21-30 > 30

TABLE 12 (CONTINUED)

7. How much does travelling to meetings interfere your normal work?

not at all	somewhat	moderately	strongly	extensively

8. How much does travelling to meetings interfere your family life?

not at all	somewhat	moderately	strongly	extensively

9. How much do you enjoy travelling to meetings?

not at all	somewhat	moderately	quite a bit	a great deal

10. How effective can you be at an meeting, when you are away from your office?

very ineffective	somewhat effective	moderately effective	quite effective	very effective

11. How many days would you prefer that travel last, for a single offical government meeting ?

< 1 day	1-2	3-5	6-10	>10

12. How much per trip should a video teleconferencing system be worth to the ROCN, if it can save you trips?

< NT$ 100	NT$ 300	NT$ 500	NT$ 1,000	> NT$ 1,000

J. SUMMARY

The economic analysis methodology proposed in this chapter is one process that may be used to evaluate the feasibility of a proposed video teleconferencing system for the ROCN. It should be noted that the results of this evaluation may be different if the assumptions are changed. The number of meetings held per year is critical, along with costs related to equipment, room outfitting, maintenance, telecommunication lease fees, travel, and productivity loss. Changing any of these factors will change the result of the final analysis. Based on assumptions used in this chapter, the 10-year average savings-minus-costs figure changes linearly as a function of the number of meetings per year, at a rate of NT$ 160,000 ($ 6,400) per additional meeting.

Some of the assumptions used here are conservative. For example, the ROCN actually holds more than 60 meetings per year between personnel at Taipei and at Kaohsuing. Outfitting two conferencing rooms normally costs less than NT$ 3,000,000 ($120,000) in Taiwan. Furthermore, it may be negotiated with the DGT that the more often the leased cable is used, the lower the telecommunications lease fee per use will be. It should be noted that, even under these conservative assumptions, the result still supports development of the selected videoconferencing system.

V. CONCLUSIONS AND RECOMMENDATIONS

This study provides answers for several questions which are related to a military teleconferencing system for the ROCN.

- What a teleconferencing system can do for the ROCN.
- What kind of teleconferencing system would best meet the ROCN's needs.
- What things must be considered in order to develop an optimum teleconferencing system.

A. CONCLUSIONS

Chapter I has discussed the ROCN's need for a modern teleconferencing system due to the continuing threat from Communist China and an ever-increasing number of meetings required for exchange of information and optimal decision making. The development of telecommunications networks on Taiwan will soon make this possible. Chapter II provides information on teleconferencing technology that is already available in the current market. Five categories of teleconferencing systems are described and five kinds of transmission media compared.

The trend throughout the world is toward videoconferencing systems. Costs of such systems are reported in Chapter II, and the feasibility of such a system for the ROCN is explored, along with the advantages and disadvantages of using fiber optics cables as transmission medium. Information in Chapters II and III answers the question concerning the kind of the teleconferencing system that will best meet the ROCN's needs. A set of components that will result in a satisfactory teleconferencing system is outlined, along with the system's basic design and requirements.

An economic analysis process has been suggested in Chapter IV that may be used to evaluate the proposed teleconferencing system for the ROCN. Using assumptions noted there, the ROCN should find it cost effective to develop the proposed teleconferencing system for military decision-making usage. As a result of this analysis, it is concluded that it is feasible and will save money and time if the ROCN constructs a domestic fiber optics-linked videoconferencing system. However, approximate figures were used for the analysis. Precise and detailed data are required to conduct a further evaluation in order to determine exactly the optimum teleconferencing system for the ROCN.

B. RECOMMENDATIONS

This study has dealt only with development of a teleconferencing system to aid ROCN officers in making military decisions. However, such a system also could be used for education, training, and medical demonstration programs. Such multiple uses would increase benefits and, possibly, cut costs. Further study is needed in this area. Several topics for follow-on research are noted below.

- What is the optimum transmission medium and teleconferencing system for the ROCN, based on actual tangible cost and benefit figures? What is its economical operating scale? What is its optimum application?
- What are the intangible costs and intangible benefits of a selected teleconferencing system, and how can these be quantified?
- What are the advantages and disadvantages of also utilizing an ROCN teleconferencing system for education and training?
- Could a fiber optics linked teleconferencing system be expanded to be a Fiber Distributed Data Interface Wide Area Network?
- What are the economic aspects of integrating an ROCN teleconferencing system with planned the Integrated Service Digital Network (ISDN)?

- Is it feasible to connect the ROCN teleconferencing system to the ROC's Department of Defense telecommunications network.

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